VOLUME X, NUMBER 4/WINTER 1981

NUCLEAR MATERIALS MANAGEMENT

Journal of the
INSTITUTE
OF
NUCLEAR
MATERIALS
MANAGEMENT

FEATURE ARTICLES

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EDITORIAL

DR. WILLIAM A. HIGINBOTHAM
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Upton, New York

According to U.S. newspapers, the IAEA has many doubtful critics. The criticisms, however, seem to be due to misconceptions as to what the IAEA is intended to do. It is authorized to perform inspections in order to "ensure, so far as it is able, that assistance provided by it or at its request or under its supervision and control is not used in such a way as to further any military purpose." It is not authorized to search for undeclared material, nor to determine whether or not a given nation has need for a particular facility. It does not generally have control of facilities and materials, and it is not able to prevent a diversion, only to report it. A signatory to the NPT can resign, giving 3 months notice.

So much for the negatives. Now for the positives:

Virtually all of the nations in the world are members of the IAEA and support it at least to some degree. It provides assistance to developing countries directly or by arranging for assistance by other member states. In the last 10 years it has taken on the responsibility for safeguarding hundreds of nuclear facilities and has developed quite credible procedures for inspections and for drawing meaningful conclusions as to their results. This effort is continuing as fast as minds and resources permit. At the very least, the existence of IAEA safeguards has encouraged nations to reveal and to describe their nuclear plans and facilities, with very few exceptions. Anyone can learn whether all of a nation's nuclear facilities are under safeguards, or only some of them. From reports, papers given at meetings, and other sources, it is possible to infer the strengths and weaknesses of the Agency today, and to learn about the progress that it is making.

The limitations of IAEA safeguards are largely due to the statutory limitations and to limited resources. The former may be corrected by agreements among interested states or by initiating discussions for supplementary international undertakings. The latter call for more technical support and larger contributions by the member states. It is a truly unique international experiment that is attempting to provide assurance, as far as it is able.

Many people tend to look on the IAEA as an investigative agency looking for national culprits. Perhaps a more useful view was recently expressed by the Director General, H. Blix: Safeguards "are measures through which states, in the exercise of their own sovereign will, rely upon an international organization to confirm through inspection that their actions conform to their stated intention not to acquire nuclear weapons. Since these states wish to convince the outside world of their continuing non-nuclear weapons status, it is in their proper interest that the safeguards should be effective."

Elsewhere in this volume there is discussion of some of these issues. The editors sincerely hope that other members will contribute to further discussion in the Journal.

On another matter, some may have read "A Safeguards Anecdote" in the last issue of the Journal. There must be many of you who could contribute similar reminiscences. Please do.

NUCLEAR MATERIALS MANAGEMENT is published five times a year, four regular issues and a proceedings of the annual meeting of the Institute of Nuclear Materials Management, Inc.

SUBSCRIPTION RATES: Annual (domestic) $40; annual (Canada and Mexico) $50; annual (other countries) $60; (shipped via air mail printed matter); single copy regular issues published in spring, summer, fall and winter (domestic) $9; single copy regular issue (foreign) $11; single copy of the proceedings of annual meeting (domestic) $25; and single copy of proceedings (foreign) $40. Mail subscription requests to NUCLEAR MATERIALS MANAGEMENT, Journal of INMM, 2400 East Devon Avenue, Des Plaines, Illinois 60018 U.S.A. Make checks payable to INMM.

DESIGN AND PRODUCTION
Design Two, Ltd.
600 North McClurg Court
Chicago, Illinois 60611 U.S.A.

INQUIRIES about distribution and delivery of NUCLEAR MATERIALS MANAGEMENT and requests for changes of address should be directed to the above address in Des Plaines, Illinois. Allow eight weeks for a change of address to be implemented. Phone number of the INMM headquarters is (312) 635-7700.

Third-class non-profit bulk rate postage paid at Des Plaines, Illinois 60018 U.S.A.

ISSN 0362-0034

CHAIRMAN'S COLUMN

GARY MOLEN
E.I. duPont de Nemours & Co.
Aiken, South Carolina

The year 1982 promises to be eventful if the experiences we had in 1981 are any indication of what the Institute can expect in the near-term future. We have completed the establishment of the Executive Headquarters in the Chicago area with John E. Messervey as our Executive Director. Thanks to the very fine and cooperative efforts of Ed and Jerry Johnson of E.R. Johnson Associates the new headquarters is operating very efficiently. Ed and Jerry really came to the aid of the Institute at its time of real need. They are true friends. Thank you both.

Our Safeguards Committee is continuing under the very capable leadership of Bob Sorenson. Bob has recruited an excellent committee and their plans for future activities are in place and running. This committee is providing a vitally needed service to the government through the talents of our members and their industrial perspectives. We have received many compliments on the very fine job this committee is performing.

The Physical Protection Technical Working Group is now under the direction of J.D. Williams of Sandia. This technical working group has done, and continues to do, an outstanding job of communicating the technology of physical protection, in all its facets, to those in greatest need of the information. The past workshops have been reported as being extremely beneficial to the participants. In addition, they have generated more than sufficient revenues to offset their cost. Those workshops planned for this next year look to be every bit as successful. Any of you who are interested should make a sincere effort to attend. I think you will find them very worthwhile.

The Annual Meeting Committee has the plans for the Washington, D.C., meeting well underway. Yvonne Ferris is serving as the new Program Chairman. As usual, she is doing a very capable job. The Program Committee is committed to making this year's meeting the most outstanding of this decade. In keeping with that commitment, the Arrangements Committee, under the tutelage of Tommy Sellers, is going all out to provide for your every need while in the Washington area. Mark Elliott, as Local Arrangements Chairman, has assembled a fine subcommittee to work out all the details for a smoothly-run meeting. Be sure and mark these dates, July 18-21, 1982, on your calendar and begin now to make plans for attending our twenty-third annual meeting. It should be a great one!

We have some new faces in our standards activities. Actually, I shouldn't say new faces, because neither Ralph Jones (new head of N-15) or Jim Clark (new head of N-14) are new faces to the Institute. Both of these gentlemen have undertaken tremendous responsibility in agreeing to direct the efforts of these two standards committees. The good reputation the Institute has as a standards secretariat is due in large part to the very leadership we've had in the past.

I want to commend both Ralph and Jim for the fine job for which I'm sure they're capable. In order for their efforts to be successful, they need your cooperation. So, please say yes when you're asked to serve. If you're not asked and you want to participate, then call Ralph or Jim (as appropriate) and let them know you want to volunteer. You'll be glad you did and so will we.

As I said, this year promises to be eventful. How eventful will depend on you. We're a volunteer organization with professional training. In order for us to do a really good job, we need a lot of people willing to contribute their time, talents and efforts. It's a worthwhile cause and we can all benefit from your cooperation.

EXECUTIVE COMMITTEE REPORT

The Institute's executive committee met in regular session February 10-11, 1982, at the Denver Marriott City Center. The Denver Marriott will host the 1983 INMM annual meeting.

The following is a brief summary of issues before the executive committee:

- Constitution and Bylaws Chairman Roy Cardwell reviewed the implementation procedures for graded membership.
- Annual Meeting Chairman John Jaech reported that plans for the 23rd annual meeting in Washington, D.C., are virtually complete. Program Chairman Yvonne Ferris reviewed plenary session speakers and specific program sessions. Arrangements Chairman Tommy Sellers reviewed meeting arrangements, the spouses' program and plans for poster sessions and exhibits.
- Bob Sorenson reported on technical matters before the safeguards committee.
- Site selection responsibilities were transferred to the executive committee. The staff was asked to provide guidance and research as appropriate.
- J.D. Williams, chairman of the technical working groups, reported on the October 5-8 workshop in Albuquerque. The executive committee also reviewed a possible waste management and transportation workshop proposed for fall of 1982.
- LRP Committee Chairman Sam McDowell's long range planning report was received with enthusiasm by the executive committee. The LRP report outlines an ambitious five-year program for INMM members.
- G. Robert Keepin was selected to serve as nominating committee chairman by Chairman Gary Molen.
- John Jaech reviewed plans for the INMM/ANS topical meeting scheduled for Hilton Head, November 27-December 1, 1983.
- The safeguards committee was asked to respond to the editor of the *Wall Street Journal* regarding an article that appeared in the February 4, 1982, issue.

John E. Messervey
Executive Director

KEEPIN APPOINTED KEY IAEA POST

JOHN E. MESSERVEY
INMM Executive Director

Dr. G. Robert Keepin

Dr. G. Robert Keepin of the Los Alamos National Laboratory has been appointed Special Adviser to the Deputy Director General for Safeguards at the International Atomic Energy Agency (IAEA) in Vienna, Austria.

"Bob" Keepin, immediate past chairman of the INMM, is well known not only to Institute members, but throughout the international nuclear community, having been prominent in nuclear safeguards for the past 16 years, and in fission physics and reactor kinetics and control during the 1950's and early 1960's. He is a fellow of the American Nuclear Society and of the American Physical Society, and is a member of the Executive Committee of the INMM. In 1973 he received a Special Award for Nuclear Materials Safeguards Technology from the American Nuclear Society which carried the citation "for his early recognition of the need for Nondestructive Assay Instrumentation, his demonstration of practical passive and active assay methods, and his leadership in implementing these techniques and gaining wide acceptance for their use". At the Los Alamos National Laboratory, he is now Program Manager for Nuclear Safeguards Affairs.

Dr. Keepin's new responsibilities at IAEA headquarters will focus on the key task of upgrading the efficiency and effectiveness of IAEA Safeguards. Initial emphasis will be on the practical implementation and routine field use of newly developed instruments, methods and techniques that form the technical basis for the IAEA's safeguards inspection and verification activities worldwide.

International (IAEA) Safeguards, which have received extensive media attention in recent months (particularly since the bombing of the Osirak reactor near Baghdad last June 8) are designed "to detect the diversion of nuclear material to unauthorized purposes and to deter such diversion by risk of early detection." This is intended to provide, in effect, an early-warning system for detecting discrepancies in nuclear material inventories (as would occur if nuclear material were diverted, lost or stolen) that can then trigger international reaction, including possible sanctions. A technically effective safeguards system that can provide such detection and early warning is clearly a vital factor in the objectivity and credibility of international (IAEA) assurances that signatory nations around the world are living up to their safeguards agreements to use nuclear materials and equipment for peaceful uses only. Much of the instrumentation and technology required to implement stringent, effective safeguards in various types of nuclear facilities has been developed by the Safeguards R & D program at Los Alamos which Dr. Keepin established in 1966 upon his return from an earlier two-year professional assignment with the IAEA in 1963-1965.

The IAEA currently carries out some 1,000 safeguards inspections annually in over 500 facilities around the world having an aggregate of more than 80 tons of plutonium, over 10,000 tons of enriched uranium and 30,000 tons of natural uranium. The record of safeguards accomplishments has in many ways been very impressive, but the task at hand is tremendous and growing as nuclear energy programs continue to expand in more and more countries of the world.

The whole issue of the effectiveness of IAEA Safeguards and their role in international stability and security issues on both the national and the global scale, continues to receive much attention in diplomatic and government circles, as well as the media. A wide range of ongoing studies, deliberations, and hearings (as, for example, in the U.S. Congress, and in similar governing bodies in other countries) continue to underscore the urgency, and the necessity, of an adequately-supported, efficient and effective system of IAEA international safeguards that can carry out the dual mandate of detection-of-diversion and assurance of safeguards compliance.

Dr. Keepin's new position as Safeguards Adviser, to begin May 25, 1982, for a period of two years, is at the Director level in the IAEA senior management structure, and, as such, is the highest position ever held by an American in the Department of Safeguards at the IAEA. He and his wife, Madge, will take up residence in Vienna in May, on a two-year leave of absence from the Los Alamos National Laboratory. As it happens, two of their five children are currently working and living in the Vienna, Austria, area.

A LETTER TO THE EDITOR

The international community has come to depend on the safeguards administered by the IAEA as a vital component of nuclear non-proliferation. In recent months, however, the technical effectiveness of those safeguards has been questioned, primarily within the United States by the Nuclear Regulatory Commission and the Senate Committee on Foreign Relations.

It must be noted that those safeguards have been successful—that no country has ever been shown to have used its participation in IAEA safeguards as a ruse to conceal its development of nuclear weapons. The bonds that unite adherents of IAEA safeguards help create a climate of mutual trust, and that trust can be the only lasting solution to the control of nuclear weaponry.

Fundamental improvements in the technical effectiveness of IAEA safeguards have been realized in recent years, and further improvements are in the works. These improvements are the result of initiatives undertaken by some of the Member States of the IAEA. IAEA safeguards are more effective now than they were, but they *aren't perfect. IAEA safeguards can and should be improved to the* point that the international community is confident that the IAEA provides the assurances it seeks.

I believe that the INMM can take pride in its role to improve the effectiveness of IAEA safeguards. The work of the Vienna Chapter of the Institute is of fundamental importance in this regard and should be given every encouragement to continue its active program. But the INMM can and must do more.

Many, many efforts have been and are underway and to improve IAEA safeguards. What better source for new ideas could be found than amidst our own membership? My suggestion is to use these pages as a forum to present and discuss new ideas, leading to Institute recommendations. To start such a consideration, I ask that the enclosed letter be published, with the hope that it will stimulate other ideas, give emphasis to the more useful suggestions that might become our recommendations.

I believe the Institute should make a concerted effort to broaden its international character, actively attempt to form additional chapters in locations outside the U.S. Countries with active nuclear programs should be encouraged to form such chapters, following the model of Japan. Also, closer bonds should be established with ESARDA, for example by providing ESARDA members the opportunity to contribute to this Journal, and to jointly sponsor symposia and training activities.

We of the Institute have provided a service we can take pride in. Let us be constructive, positive and optimistic; let us suggest together how further improvements might be made.

Yours sincerely,

Thomas E. Shea

Thomas E. Shea, Ph.D.

In response to Dr. Shea's request, a copy of the "enclosed letter", referred to above, is reproduced below, in order to stimulate discussion as to what the role of the IAEA should be and how we as individuals or as an organization can assist the Agency. Since the letter includes some possibly controversial suggestions, we solicited one set of comments for inclusion in this issue. However, *we hope that this will not end the discussion. Journal readers are* invited to comment on any of these three items or on all of them. These are important issues.

December 15, 1981

The Honorable Charles H. Percy,
Senator from Illinois
Chairman
The Committee on Foreign Relations
The United States Senate
Washington, DC 20510

Dear Senator:

I want to thank you for the opportunity to testify at the Committee Hearings on December 2, 1981, delving into the effectiveness of the non-proliferation safeguards administered by the International Atomic Energy Agency. Many important considerations were brought out, which will be of unquestionable value in efforts to strengthen the existing non-proliferation regime in general, and the IAEA in particular.

It is clear that the current level of IAEA safeguards effectiveness is inadequate to provide the non-proliferation assurances we seek. This apprecition is, in itself, an essential prerequisite to improvement. But recognition within the United States is not enough: that appreciation must be widely shared within the international community before substantial improvements can be brought into effect.

Having established that a problem exists, what might be done to bring about improvements? Some suggestions have already been expressed; of those, some will succeed, some will meet with considerable resistance within the IAEA and within the international community. In the interests of improving the effectiveness of IAEA safeguards, in the following paragraphs I submit a number of additional possibilities, intended to augment the list of those already identified. On the basis of my IAEA service, I believe each would *contribute improvements, and each could be accommodated* within the existing framework of international agreements.

1) Questions have arisen regarding whether or not the Osirak (Tamuz) reactors were intended to serve a legitimate peaceful purpose. One possibility to allay future concerns of this nature might be to expand the authorities granted to the IAEA, to make a determination regarding each project initiated within a state, or each international transfer, that the declared uses are consistent with accepted patterns of peaceful nuclear development, appropriate to the state at the time the project is proposed. It would be necessary to reach international agreement on normal patterns of peaceful nuclear development, and to grant the IAEA the authority and responsibility to express its approval or disapproval before any such project is consummated.

2) If we want the IAEA to improve, to perform a vital mission for us, and we want to use their activities in something as direct as U.S. export licensing, in fairness we must tell the IAEA precisely what we expect, make certain they are given the wherewithal to do what we want, and then, then we must hold them accountable for meeting our needs.

   The IAEA is in the process of adopting an evaluation scheme for judging the effectiveness of its safeguards. Using that scheme, minimum performance targets could be identified for each type of nuclear material subject to IAEA safeguards. The IAEA could then plan its programs and measure its progress in terms of meeting those performance targets. Serious consideration should be given to organizing U.S. assistance efforts in relation to that framework.

3) Within the United States, we have experts able to define the inspection activities which should be adequate for the IAEA to implement effective safeguards. One means to provide assurance that U.S. interests would be served in any export would be to provide the IAEA with a detailed description of the minimum safeguards considered necessary, granting approval for the export only when the IAEA had acknowledged its agreement to implement its safeguards in accordance with that description (or some mutually agreeable alternative). Such a description would include the basic approach to be followed, the equipment to be used, the schedule of inspections to be performed, the inspection activities to be undertaken on each inspection, descriptions of the anomalies which should be detected in the event a diversion occurs, and a list of follow-up actions which should be undertaken in the event anomalies are detected to establish whether or not a diversion is suspected.

4) Working with other members of the international community, we should help the Agency to be capable of being more effective. Consider the following:
   - THERE JUST AREN'T ENOUGH INSPECTORS. Listen to what the IAEA is telling us in its annual Safeguards Implementation Reports. For example, they say that they need at least twice the number of inspectors now that they had in 1980 to be able to provide the minimum coverage necessary. Note that the basis they use for reference is not agreed as the minimum necessary; rather, reference is with respect to *the numbers negotiated in facility attachments*, some old, some new. The actual figures are likely to be considerably higher.
   - A LOT OF FACILITY ATTACHMENTS ARE OUT OF DATE. The Agency should review all of its facility attachments to ensure that the provisions allow the Agency the opportunity to satisfy their own criteria. This activity would not require a very great effort and would at least assure that safeguards are being applied on an equivalent basis.
   - IMPROVE PERSONNEL SELECTION. The Agency is currently not able to interview candidates before selection, and can't get rid of its duds before the contracts expire. Improvements could be brought into effect by more active recruiting (e.g., direct mailing to all nuclear establishments, plus expanded advertising in appropriate journals) and pre-employment screening. Within the U.S., we might take more of a lead to prepare candiates for IAEA employment, especially those from developing countries, having them take intensive training at Los Alamos and Sandia laboratories, for example.
   - IMPROVE INSPECTOR SUPPORT. There isn't enough help within the Agency, and many times it does not appear to be well directed. This is especially true in the support given by the information treatment division. The emphasis must shift to supporting the inspectorate with applications programs and an adequate number of data processing specialists to help make important information available, to make the information system slave to the inspectorate, rather than vice-versa.
   - INSPECTORS SHOULDN'T GO OUT ALONE. EVER! Even inspections at simple facilities should be undertaken by a team, minimum size: 2! Inspectors face a crowd of people from the facility and from the national authority. They are subjected to scrutiny, questions, the hardships of extensive travel often under trying conditions. I believe that the current policy is an unwise economy which can only lead to poor morale and ineffectiveness.
   - BUILD INSPECTION TEAMS TO COVER THE REQUIRED TASKS. Some progress has been made in this direction, but more should be done. The lead inspector must be technically competent and well trained in matters related to diversion, verification, and the rights and authorities of the Agency and the state. The inspection team should be made up of junior inspectors and non-professional inspection assistants trained in making measurements, applying seals, auditing accounts, etc., performing these needed tasks under supervision while relieving the lead inspector to marshal the information necessary to derive the conclusions required, and to investigate anomalies, preferably as they are identified.
   - IMPROVE INSPECTION QUALITY ASSURANCE. Further efforts are needed by the IAEA to improve the manner in which inspections are planned and conducted. One means to improve planning would be to help the Agency formalize its inspection planning, briefing and de-briefing, perhaps using the procedures adopted in the Agency's Euratom Section as a model. As a means to improve the quality of inspections, the Agency should create a team (or teams) of senior inspectors to accompany regular inspection teams to determine the adequacy of the safeguards approach and critique the inspections. Such a group should be coordinated through the Safeguards Evaluation Section.
   - ESTABLISH AN ANOMALY REVIEW GROUP. At present, anomalies are defined somewhat differently in the six regional sections, and the follow-up actions undertaken are not standardized and not controlled. An effort should be made to reach a common definition on just what constitutes an anomaly, and what actions should be taken to determine whether or not a diversion may be indicated. The anomaly review group should be given sufficient authority to recommend special inspections where appropriate, and to suggest (order?) facility operators to take the actions necessary to bring about the prompt, unambiguous resolution of outstanding anomalies, once identified.
   - GET THE AGENCY TO REPORT MORE. For example, the Agency could report the details of the anomalies it detects (currently on the order of 200 per year), especially those that remain unresolved. They needn't be keyed to specific facilities or states, and thus this information could be provided under existing disclosure arrangements. Perhaps the Secretariat

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should make a report at each and every Board meeting, describing the unresolved anomalies and the means used to resolve those which had been attributed to innocent causes.

- IMPROVE REPORTING TIMELINESS. The current reporting scheme requires delays (e.g., transactions are reported by month, a month after they occur—at best), and is hopelessly cumbersome. Commission a study to recommend adoption of reporting based upon telecommunications links, expanding on the "recover" project work.
- PROVIDE GUIDANCE TO STATES ON THE BASICS OF NUCLEAR MATERIAL ACCOUNTING AND CONTROL. Agency inspectors are presented with a mind-boggling mish-mash, which they must struggle to understand. Generally this isn't the result of any mischievousness, rather, no guidance is available and entropy triumphs. The IAEA issues an extensive series of safety guides suggesting how states should regulate siting, construction, operation,..., features pertaining to nuclear facilities—some efforts are certainly needed in records keeping, inventory taking, error estimation,... to improve the basis on which safeguards are built.

5) For effective IAEA safeguards, the United States must continue to support the IAEA directly and continue the Program of Technical Assistance to the IAEA. Without the former, there is no IAEA; without the latter, there is no hope for improvement.
6) More concern must be given to the human factors aspects of IAEA safeguards, especially to attitude formation, vigilance and motivation. Some of the items noted above might help in this regard, and one other possibility comes to mind. Just as a football team is more likely to win when the crowds are cheering, we should expect the IAEA staff to be responsive to the support and encouragement of its member states. Further effectiveness could be gained through simple steps intended to reinforce the sense of importance, the concern and support felt within the community. For example, why not gather the entire safeguards staff together in a big room with the Agency's Board of Governors, and have them express in person their support. Of all the recommendations above, I suspect this one would be most cost-effective. Challenge the staff to improve, and provide the climate where improvements are eagerly sought and rewarded. That will help.

The United States is at the forefront of virtually all improvements in the effectiveness of IAEA safeguards. We can do more, especially in the sense of demonstrating how things should be. The application of IAEA safeguards in the U.S., especially at the Exxon fuel manufacturing plant in Richland, Washington, is an example of the best kind of leadership we can provide. Under the current terms of the U.S./IAEA safeguards agreement, the IAEA will shift its safeguards to another facility in another year, and the IAEA will no longer be able to derive the full and very positive benefits of this effort. Some arrangement should be created to continue this arrangement as a base for advanced training and demonstration.

Also, we could extend our activities in demonstrating how things should be. The Allied General Nuclear Services Company, operators of the Barnwell Nuclear Fuels Processing Plant have proposed an extended test of the implementation of international safeguards at their reprocessing facility. The tests would not (in the first year) include actual use of spent fuel and no plutonium would be processed, but even with these limitations, that facility represents the state-of-the-art in reprocessing safeguards technology, and the proposed experiments would contribute to further improvements. Serious consideration should be given to funding that experiment, with the active participation of the IAEA and open to all interested nations of the world.

If the human species is to survive, international accommodations must one day evolve which will allow life free of international conflict. Existing nuclear arsenals may then be allowed to deteriorate into disuse, without replacement. We must hold the world together until that time, for as many decades or centuries as it takes.

The Treaty for the Non-Proliferation of Nuclear Weapons, and the safeguards applied by the International Atomic Energy Agency are vital to preventing the spread of nuclear weapons. Every effort must be made to gain acceptance of the NPT by all nations, and to strengthen the bonds that unite the NPT community. There are very few holdouts—each should be examined to identify the steps needed to gain that country's acceptance. We should be prepared to offer incentives, pressures, security alliances; we should, if need be, be prepared to acknowledge the nuclear weapons capability of nations which are not currently enshrined in the NPT as "weapons states."

As new goals and priorities are established for the IAEA, the following points should be recalled:

- No case has ever been shown where IAEA safeguards have failed—where a nation has developed nuclear weapons under the ruse of false participation in IAEA safeguards, or by escaping detection;
- View this unique undertaking in concert with the intrinsic value of international verification, with diplomatic initiatives to reduce incentives for proliferation, and
- Bearing in mind that perfection can never be achieved, define these new goals to give measurable improvements.

With every wish for success in this effort, and all due respect,

Thomas E. Shea, Ph.D.
Vice-President
INET Corporation

COMMENTS ON TOM SHEA'S LETTER TO SENATOR PERCY

In his letter to Senator Percy, Dr. Shea suggests several ways by which IAEA safeguards might be improved. Some suggestions involve better personnel management practices by the Agency in connection with inspector operations, which the Agency might implement with available resources. Others would require substantial increases in financial support, for which the Agency must depend on increased contributions from member states. While the US advocates strengthened safeguards, our contribution remains constant and, therefore, it is actually declining because of inflation. Still other suggestions for improvements would require renegotiation of facility attachments and the extension of authority of the Agency beyond that which is provided in the Statute, which is the basic instrument of agreement under which the IAEA operates. Rather than give serious consideration to such sweeping changes to satisfy what some US critics perceive to be the Agency's inability to fulfill US expectations, let us consider the role of IAEA safeguards from the world perspective of its 106 member nations, and in the context of international efforts to control the spread of nuclear weapons.

The US non-proliferation policy must necessarily consist of two separate elements: those measures that are truly international, which are based on overwhelming consensus of all states, and those which can be unilaterally imposed by the US or in concert with a few other advanced states with similar views. Failure to maintain that distinction will be especially damaging to the fragile structure of common interests that is the basis for the international arrangements.

The US non-proliferation policy, embodied in the Nuclear Non-proliferation Act of 1978, is based on selective control of exports of nuclear materials and technology. The Act provides that *exported materials, and materials produced by exported facilities,* shall be under IAEA safeguards. Specifically in cases where subsequent reprocessing or separated plutonium is involved, foremost consideration is to be given the capability of safeguards to provide "timely warning", defined as notification to the US of any diversion well in advance of the time in which a non-nuclear-weapon state could transform the material into an explosive device (Sec. 303.(a)).* Thus, a cornerstone of US non-proliferation policy is the assumption that IAEA safeguards are capable of a degree of performance that the US policymakers have led themselves to expect. We hear, increasingly, cries of dismay that safeguards cannot prevent diversion, only detect it. Some fault the Agency further by charging that safeguards aim only to detect diversion within the few days required to make a weapon, leaving no remaining time for preventive action to be taken before an explosion would occur.** The realities of the time required to assess safeguards inspection results and to agree on decisive action must surely be apparent to all, when we recall the times required by NRC to conclude that material may have been missing, and especially when we consider the much more severe constraints under which an international inspection agency must operate.

By committing US non-proliferation policy to unattainable and unrealistic expectations of IAEA safeguards performance, we are endangering the whole structure of international control. The current barrage of criticism for failure to fulfill those expectations comes at a time of tension caused by Israel's violent action and dissension among IAEA members and NPT parties over the alleged failure of advanced nations to share nuclear resources.

We must preserve the IAEA system for what it is and cultivate it for what it can become—a truly international institution to provide assurance that nuclear activities are peaceful. There *will* be peaceful nuclear activities—they will not be stopped by attempts to outlaw them or to withhold technology. We must provide some way of allaying the suspicions of apprehensive neighbors and rivals, and that is the principal function of IAEA safeguards. Their function is not to provide a burglar alarm that meets the technical specifications of US policymakers, as a basis upon which export licenses can be granted.

The effectiveness of US non-proliferation policy is limited by a number of external factors beyond our control: (1) imports are not necessary for a state to produce weapons; (2) the US is not the sole source of materials or technology, and (3) attempts to pressure recipient states induce them to avoid dependence on the US. The feasible limits of the present policy are, therefore, to avoid US contribution in any way to possible means of producing weapons. We can effect such a policy unilaterally: on the basis of intelligence assessments, policy analysis, and IAEA safeguards findings interpreted in any way we choose, we can arbitrarily deny exports. However, if we attempt to rationalize approvals or denials on the basis of "proof" provided by IAEA safeguards, we will only succeed in destroying confidence in the IAEA system, as the infeasibility of obtaining such "proof" becomes widely apparent.

My criticism of Dr. Shea's second and third recommendations to Senator Percy is that he envisions IAEA safeguards principally as a US tool, and he believes that it is feasible to meet the performance requirements that have been articulated by the critics, if only those requirements were made more specific and more technical effort were applied. Even if that were true, IAEA safeguards need to be recognized as part of an international institutional structure that must command the confidence and support of the entire membership, and especially the Third World. IAEA safeguards cannot be tailored to unrealistic requirements of the US non-proliferation policy without destroying the entire structure of international cooperation.

To keep things in proper perspective, we need to continually remind ourselves that the overwhelming danger is the US-Soviet nuclear arms race, as other countries keep telling us. They are right. The function of safeguards is in a different area—to prevent peaceful nuclear activities from generating fears and suspicions among the non-weapon states that would lead to mini-arms-races and conventional conflicts. Safeguards cannot prevent a determined state from obtaining nuclear weapons. We must not allow fears and suspicions generated by legitimate nuclear programs to induce any state to do so. That is the real need for IAEA safeguards.

J.M. de Montmollin

*The House Committee on International Relations, in its report on the bill, stated that safeguards for conventional reprocessing technology producing separated plutonium could not meet the Committee's standard of a few days or weeks, but that they expected INFCE to provide alternatives that would (House of Representatives, 95th Congress, 1st Session, Report No. 95-587, p. 19).

**NRC Commissioner Gilinsky, as quoted in NuclearFuel, January 18, 1982, p. 3

INMM EXECUTIVE COMMITTEE
CHAIRMAN Gary F. Molen
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Vienna	Djali Ahimsa
Central	Harvey Austin
Southeast	Mary Dodgen
Northwest	Bob Carlson

INMM CALENDAR OF EVENTS

MARCH 16-19, 1982
Technical Workshop on Physical Security
Marriott's Tan-Tar-A Resort
Osage Beach, Missouri

APRIL 27-29, 1982
ESARDA Specialist Meeting
Energieonderzoek Centrum Nederland (ECN)
Petten, The Netherlands

JULY 18-21, 1982
INMM 23rd Annual Meeting
Hyatt Regency Washington
Washington, D.C.

OCTOBER 5-8, 1982
Physical Protection Workshop
Sheraton Old Town
Albuquerque, New Mexico

JULY 10-13, 1983
INMM 24th Annual Meeting
Denver Marriott City Center
Denver, Colorado

FERRIS NAMED ROCKWELL ENGINEER OF THE YEAR

Yvonne M. Ferris

Rockwell International's Yvonne Ferris, a Denver resident, was recently selected as the 1982 Rocky Flats Engineer of the Year and the Engineer of the Year for Rockwell's Energy Systems Group. She is one of 15 outstanding engineers to be honored at the annual Rockwell Engineer of the Year awards banquet February 24th in Pittsburgh.

Yvonne, manager of Statistics and Systems Analysis at Rocky Flats, will be recognized for her outstanding contributions to Rockwell, her work in the statistics profession since 1956 and the nuclear industry nuclear materials accountability program. Rockwell will honor Mrs. Ferris in conjunction with National Engineers Week set for February 21-27. Rockwell employs one-tenth of the nation's engineers. Some 15,000 engineers and scientists work in research and development functions. The theme for the Rockwell awards program will be "Engineers: Pioneering America's Revitalization." Appropriately, the 1982 Engineers Week poster features a drawing of the Rockwell-built Space Shuttle.

Rockwell's Yvonne has worked at Rocky Flats in the statistical field since 1956. She received a BS degree in statistics from Iowa State University in 1956 and has also studied at the Rochester Institute of Technology, University of Colorado and University of Vienna. In addition to INMM, Yvonne is a member of the American Statistical Association, American Society for Quality Control and the Rocky Flats Chapter of the National Management Association.

She will receive a Leonardo da Vinci Medallion from Rockwell. The medallion, struck in fine silver, portrays the engineering accomplishments of its namesake.

WELCOME TO WASHINGTON, D.C. JULY 18-21, 1982

Our 23rd annual meeting local arrangements committee welcomes you to Washington, D.C. Committee members, Mark Elliott, Mary Clark and Joe Tinney, have been busy gathering visitor information to assist you in planning your tours of the nation's capital.

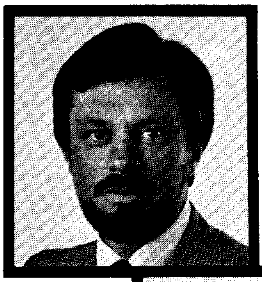
If you would like to visit the White House during your stay, you should write to your senator or representative to arrange for the "early morning" tour. Be sure and give him or her a specific date and the number of tickets you will need. The White House is closed to visitors on Sunday and Monday.

The Japanese Embassy is one of the most beautiful embassies in Washington. A tour of the embassy will be the highlight of our spouses' program. From the embassy, we will be transported to Georgetown where shopping and fine dining opportunities abound. We will also visit the exciting new Georgetown Park Mall, returning to the Hyatt on Capitol Hill by mid-afternoon.

On Tuesday evening, our banquet will be held in the formal dining room of the Rayburn Building, one of the newest buildings in the Congressional complex. The Rayburn Building is home for many of our representatives. We are sure everyone will enjoy this evening on Capitol Hill.

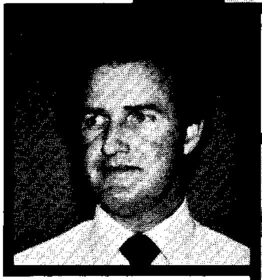
If you have any questions prior to our annual meeting, please feel free to write Mark Elliott, Chairman, INMM Arrangements Committee, c/o International Energy Associates Limited, 600 New Hampshire Avenue, N.W., Suite 600, Washington, D.C. 20037.

See you in July.



Mark Elliott

Mary Clark



Joe Tinney

Theresa Williams-Barnes

U.S. Capitol, Washington, D.C.

BOOK REVIEW

LESLIE G. FISHBONE
Brookhaven National Laboratory
Upton, New York

The Fifth Horseman, Larry Collins and Dominique Lapierre, Simon and Schuster, New York, 1980.

A hydrogen bomb smuggled into New York City? Could there be safeguards, customs, and intelligence failures significant enough to permit this to happen? Yes, according to the chilling novel *The Fifth Horseman* (meaning terror; the allusion is to the Four Horseman of the Apocalypse in the book of Revelation, 6:8, in the New Testament).

The story is this. A message is delivered to the White House stating that in sixty-three hours a thermonuclear weapon will be detonated in New York City unless Israel withdraws from the West Bank of the Jordan River and from East Jerusalem and allows the Palestinian people to enjoy full sovereign rights. The message, signed by Muammar al-Qaddafi, the President of Libya, also promises instant detonation if a preventive evacuation is attempted. Government response is immediate at the level of the National Security Council. The veracity of the message and its accompanying bomb description are ominously verified through the remote viewing of a test explosion in the Libyan desert. Moreover, the bomb is set to detonate unless a deactivating signal is sent.

The American President begins trying to convince the Libyan leader to act "more" reasonably. But the latter is insistent that the Palestinian people have suffered too long. What will the U.S. Government do to prevent millions of deaths in New York City?

Israel, when its leadership learns what has happened, initiates almost instantly a nuclear attack on Libya. But the airplanes are recalled before they carry out the attack; the United States and the Soviet Union had applied crushing political pressure on Israel.

Frantic efforts ensue to find the bomb. Federal agents throughout the country join New York City detectives in a traditional but painstakingly thorough combing of the city for leads. Meanwhile, nuclear-explosive search teams (NEST) from the U.S. weapons laboratories rush to New York with their arrays of neutron and gamma detectors. Finally, the intelligence services of friendly countries are contacted for possible relevant information.

Much of the book is a recitation of how one detective uses his years of street experience to perceive the significance of clues he uncovers in an ultimately successful attempt to find the weapon. The NEST teams are foiled by the limited sensitivity of their equipment and by spurious signals emitted by pigeons flying about with plutonium attached to a leg, a ploy concocted by the culprits who constructed and transported the weapon. Who are they? Three Palestinians, two brothers and a sister, of whom one brother had worked for many years in the French civilian nuclear program and had been threatened with death if he did not participate in the plot.

How was the bomb constructed, or to put the matter differently, what safeguards concerns are exploited? First, the plutonium needed for the bomb's fission trigger came from a French-built Libyan reactor. (Only now are there plans for Libya to receive a small power reactor from the Soviet Union.) The French chief scientist there had been blackmailed into faciliting the diversion, which proceeded as follows. A false report was sent to the International Atomic Energy Agency (IAEA) that a fuel failure necessitated replacing fuel after a very short burnup (best for weapons-grade plutonium). Reactor records and instruments were intentionally altered to indicate false radioactivity in the coolant. IAEA inspectors watched the fuel transfer and were deluded by the records. After the inspectors left, the spent-fuel assemblies were removed from the cooling pool. A before-the-lens tamper (pictures of the pool) fooled the continuously operating IAEA surveillance cameras while the real assemblies were replaced by dummy assemblies loaded with cobalt-60 to produce Cerenkov glow and to mimic at least one aspect of the gamma spectrum from spent fuel. Thereafter, reprocessing took place in a plant built from freely published designs. Voila, weapons-grade plutonium! To construct a thermonuclear weapon, important design features were extracted from reports of key laser-fusion experiments purloined from another French scientist, murdered during the theft. It is fittingly ironic that the French intelligence service is enormously helpful in identifying the culprits and thereby aiding the search.

Aside from a minor technical error on the possible rate of reprocessing, the misspelling of "Cerenkov", and the questionable implication that Israel once obtained highly enriched uranium surreptitiously from an American source, the book is good in its technical detail. However, the plot is implausible in two major respects: the unlikelihood that such a bomb project could be carried out in a country lacking in technical and industrial experience and the absence of a fission bomb test before a fusion bomb test. Concerning the latter, it seems most improbable that such a step could be taken without expert advice, of which there was none, from an experienced weapons designer. Indeed, the smuggling of a fission bomb rather than a fusion bomb into New York City would probably not alter the realistic responses expected from Government agencies. Tens of thousands of deaths are already catastrophic.

Though not great literature, *The Fifth Horseman* is a masterpiece of suspense that kept this reviewer reading late into the night. It could not fail to interest every reader of this Journal, whose professional obligation it is to do everything possible to prevent the plot events from occurring.

TECHNICAL WORKING GROUP ON PHYSICAL PROTECTION REPORT

JAMES D. WILLIAMS, CHAIRMAN
Sandia National Laboratories
Albuquerque, New Mexico

General

The Institute of Nuclear Materials Management (INMM) established the Physical Protection Technical Working Group to be a focal point for INMM activities related to the physical protection of nuclear materials and facilities. This working group is in the process of increasing the quality and quantity of physical protection papers presented at the INMM annual meeting. Those of you working in the physical protection area should refer to the inside front cover of this Journal for the call for papers and, if time permits, consider submitting a paper for a regular or poster session. Other activities of the working group have included the sponsorship of technical workshops with emphasis on intrusion detection, entry control, and security personnel training. The plan for these workshops has consisted of a series of small informal group discussions on specific subject matter to allow direct participation by attendees and to allow exchange of ideas, experiences, and insights. Perhaps a more important aspect is becoming personally acquainted with persons working on problems similar to their own. Workshops on other topics within the physical protection area will be sponsored if sufficient interest exists. In the following sections a few details are presented about workshops that are presently scheduled or in the planning stages.

Physical Security Workshop

March 16-19, 1982

We are extremely fortunate to have Mr. Thomas H. Isaacs, Deputy Director, Office of Safeguards and Security, U.S. Department of Energy, and Mr. Robert F. Burnett, Director, Division of Safeguards, Nuclear Regulatory Commission, to participate in the opening session and in the workshops dealing with DOE and NRC rules and regulations.

Tentative plans also include a speaker from the Federal Emergency Management Agency (FEMA) for our banquet speaker and Mr. Robert L. Barnard, MERADCOM, Author of *Intrusion Detection Systems: Principles of Operation and Application,* for our luncheon speaker. The title of Mr. Barnard's talk will be "Sensors in Hostile Environments."

New this year will be vendor presentation of a few intrusion detection systems. The information gained from the questionnaires sent with each meeting invitation will be used to schedule the workshop sessions and for vendor selection.

A partial list of proposed topics includes:

- *Contraband Detection and SNM Detection* will discuss the detection of explosives, drugs, alcohol, metals and SNM using various commercially available systems including canines.
- *Positive Personnel Identification and Access Control* will discuss the merits and shortcomings of the various credentials associated with access control. Systems using physical personal characteristics will also be discussed.
- *Security System Maintenance Philosophy* will address the who, when and how of maintaining security hardware.
- *Alarm Assessment by Video, Guard Towers, Etc.* to provide information to the response force to aid them in determining the cause of the alarm.
- *Barriers* will discuss the value and effectiveness of both active and passive barriers to assure adequate response time for the guard force to approach an intruder before facility sabotage occurs.
- *Minimization of False Alarms by Combination of Sensor Logic* deals with selective grouping of various redundant intrusion detection systems to lower the false alarm rate and improve the probability of detection.
- *Special and/or Unique Application of Sensors* to protect piping, steam lines, storm drains, etc.
- *Security of Communications* will discuss the detection of surreptitious listening devices.
- *Security Surveys and Planning for Security Equipment* will discuss site surveys and reviews necessary for proper selection of equipment.
- *Vehicle and Material Access to Protected Areas* will discuss inspection and control techniques.
- *Performance Testing of Interior Sensors*
- *Performance Testing of Exterior Sensors*
- *Performance Testing of Closed Circuit Television Systems*
- *Security Lighting Design* will discuss various techniques for design of plant lighting, evaluation of the merits of various types of lighting (Metal Halide, Mercury, High Pressure Sodium, etc.), compatibility of plant lighting with the environment and other security systems.
- *Review of DOE Rules and Regulations*
- *Review of NRC Rules, Regulations and Inspections*
- *Exterior CCTV* will include the design, installation and maintenance of exterior CCTV and motion detection systems.
- *Contingency Planning* will review the use of risk analysis techniques to determine threat assessment and site attractiveness, to develop contingency plans and policy to deal with bomb threats, extortion, etc.

Physical Protection Review

October 5-8, 1982—See inside back cover of this Journal for names, addresses, and telephone numbers of persons to contact.

"Physical Protection Review—Getting the Most for Your Money" is the title of the workshop to be held in the Sheraton Inn, Old Town, Albuquerque, New Mexico. Albuquerque and New Mexico are a natural blend of the old and the new. Today the State is a center of space-age research and development, but our workshop will be held just a short distance from San Felipe de Neri, which was the first building erected in 1706 when Albuquerque was founded. From that beginning, Albuquerque has continued to be a business

continued on page 14

continued from page 13
and trading center. By 1800, a few trappers and "mountain men" from the new country, America, began to venture into New Mexico. One of the earliest visitors of note was Lt. Zebulon Pike in 1806. He had been captured in Northern New Mexico, and on his way to Mexico under guard, spent a few days in Albuquerque as the prisoner-guest of the padre at San Felipe.

In.1821, New Spain (present Mexico) declared its independence from Spain, and New Mexico became a department of Mexico. In 1846, General Kearny raised the Stars and Stripes over the Plaza and Albuquerque became an army post as well as a supply center for the many forts in the Southwest during territorial days.

Early in the Civil War, the Confederates captured Albuquerque and their flag flew over the Plaza for several weeks. When they retreated, they buried six cannons near the Plaza, one of which is presently displayed.

In 1880, the railroad came through New Mexico and its route lay two miles east of Albuquerque. Immediately New Albuquerque was born along the tracks, and the two communities lived separate lives for many years joined by a horse drawn streetcar down Railroad Avenue. Eventually New Albuquerque met Old Albuquerque, engulfed it, and then went miles beyond. In 1949, it was finally incorporated into the City, and a few years later a historic zone was established to ensure the preservation of Old Town's authentic character.

The gas lit plaza and wrought iron benches invite the visitor to shed his worries and assume a slower, more relaxed pace. Dozens of attractive galleries and shops offer contemporary and traditional arts and crafts from all the cultures that have combined harmoniously to produce the rich heritage that is Albuquerque's. Restaurants feature exotic New Mexican foods. Venerable Old San Felipe Church watches benevolently over the Plaza. This is another world where yesterday and tomorrow are on elbow-rubbing terms.

Coupled with the lure of Old Town is the fact that the workshop has been scheduled to coincide with the International Hot Air Balloon Festival. More than 500 balloon crews will be participating and large numbers of observers make late hotel/motel reservations difficult to obtain. In order to ensure the proper number of rooms, the Sheraton Old Town has requested that firm reservations be made in early July. This workshop is intended to attract approximately equal numbers of people from the Department of Energy and their contractors, the Department of Defense and their contractors, the Nuclear Regulatory Commission and their licensees, and high security commercial industries. The purpose is to have a series of workshops in which ideas can be shared, hopefully to save the entire community the cost of redundant activities and result in more effective physical protection systems.

Central Control and Information Display Systems
Late January 1983 (Tentative)—Contact Larry Barnes
Allied Genral Nuclear Services
P.O. Box 847, Barnwell, SC 29812
Telephone (803) 259-1711.
This workshop is presently in the planning stage and the topics planned relate to controlling and displaying security, fire, safety, and other information on how to integrate such systems into a facility operation plan. Please contact Larry to express your interest in this workshop and possible discussion topics.

Security Personnel Training
Summer 1983 (Tentative)—Contact Dr. L. Paul Robertson
Division 1716
Sandia National Laboratories
P.O. Box 5800
Albuquerque, NM 87185
Telephone (505) 844-7706.

The third workshop concerning the training of security personnel is in its very early planning stages. If you have ideas of topics to be covered or suggestions to make about this workshop, please contact Paul.

GERDIS JOINS PUBLIC SERVICE INDIANA


Thomas A. Gerdis, Jr.

Thomas A. Gerdis, Jr. of Louisville has joined Public Service Indiana as community relations supervisor, nuclear, at the company's Marble Hill office located near Madison.

A native of Berlin, Conn., Gerdis was previously employed as the assistant director of public affairs for U.S. Ecology, Inc., at Louisville. He has also been employed as managing editor of the Institute of Nuclear Materials Management Journal and as engineering news editor at Kansas State University.

In his new position, Gerdis will be responsible for a variety of activities directed at increasing public awareness and understanding of Marble Hill and nuclear power.

A 1963 graduate of Evangel College at Springfield, Mo., with a bachelor of arts degree in history and sociology, Gerdis received a masters degree in mass communications and public relations from Kansas State University in 1970.

Gerdis serves as the vice chairman of the Central Region Chapter of the Institute of Nuclear Materials Management and is a member of the Public Relations Society of America and the Jeffersontown Covenant Church.

He and his wife, Judith, have three children, Trina, 10; Joel, 7, and Micah, nine months.

MEMBERSHIP COMMITTEE REPORT

JOHN E. BARRY, CHAIRMAN
Gulf States Utilities
Beaumont, Texas

1982—THE YEAR OF UPTURN?

The year 1981 went out on the downside for many areas of the nuclear industry. During the past year the international uranium market hit bottom at less than half the peak value (in constant dollars) registered in 1978. The present increase in near and longer term purchase activity indicates uranium prices will improve in 1982 albeit not meteorically.

In the U.S. six more nuclear power projects were cancelled in 1981 and many more, including our own River Bend One, were further delayed. While definitely not a positive sign, that score-card was less disastrous than the overwhelming number of such events suffered in 1980 in America. During 1982 we hope to see the utilities financially cope with completion and the NRC administratively function to license approximately thirty-three nuclear plants for operation by the end of 1983. Happily it appears that elsewhere nuclear power development is less uncertain.

The year 1982 may also be a year of reckoning for international safeguards cooperation. Reportedly the U.S. government may soon approve the sale of commercial plutonium obtained from French reprocessed, U.S.-origin fuel by the Swiss. Depending on its destination on the Continent (e.g. France or West Germany) it could be the first such approval for shipment to a non-weapons state since the passage of the Nonproliferation Act of 1978.

Optimistically this year may be a good and active year for nuclear power worldwide, and consequently a growing one for INMM membership:

The following eighteen individuals have been accepted for membership during the period October 1, 1981 through December 31, 1981. To each the INMM Executive Committee extends its welcome and congratulations. New members not mentioned in this issue will be listed in the Spring 1982 (Volume XI, No. 1) issue.

Winston C.H. Alston, Group Leader, Safeguards Inspection, International Atomic Energy Agency, P.O. Box 200, A-1400, Vienna, Austria

Patricia W. Baird, Programmer/Analyst, Union Carbide Corporation, Nuclear Division, Bldg. K-1007, Mail Stop 007, P.O. Box P, Oak Ridge, TN 37830, (615) 574-8441

William B. Cheney, Safeguards Inspector, International Atomic Energy Agency, P.O. Box 100, A-1400, Vienna, Austria

David L. Davenport, Security Supervisor, Gulf States Utilities Company, P.O. Box 220, St. Francisville, LA 70775, (504) 635-4514

William J. DeRossell, Plant Protection Dept. Head, Union Carbide, Nuclear Division, P.O. Box P, MS 407, Oak Ridge, TN 37830, (615) 574-8345

Lorin S. Gowdy, Training Officer, Green Mountain Security, c/o Yankee Atomic Electric Company, Rowe, MA 01367, (413) 625-6140

Larry Michael Gray, Material Management Coordinator, Union Carbide Corporation, P.O. Box X, Bldg. 3037, Oak Ridge, TN 37830, (615) 574-7024

Connie P. Hall, Accounting Supervisor, UCC-ND Y-12 Plant, P.O. Box Y, Building 9724-11A, Oak Ridge, TN, (615) 574-2593

Tadatsugu Ishikawa, Safeguards Inspector, International Atomic Energy Agency, Rm. A1602, Vic, P.O. Box 200, Vienna, Austria

Janice V. McGee, Director Adm. Services, Duquesne Light Company, P.O. Box 4, Shippingport, PA 15077, (412) 643-5301

Hisamoto Miyauchi, Manager, Nuclear Engineering Section, The Hokkaido Electric Power Co., Inc., 2, Higashi, 1-chome, Ohdori, Chuo-ku, Sapporo, Hokkaido, Japan

Russell Pierre, Jr., Supervisor, Nuclear Materials Engineering, Goodyear Atomic Corporation, P.O. Box 628, Piketon, OH 45661, (614) 289-2331, Ext. 2428

Thomas Hamilton Sanford, Manager, Safeguards and Security, EG&G Idaho, P.O. Box 1625, Idaho Falls, ID 83415, (208) 526-2373

Peggy Harvey Scott, Programmer/Analyst, Union Carbide Nuclear Division, Box P, MS 65, Bldg. K-1007, Oak Ridge, TN 37830, (615) 574-8398

Charles Leland Tyrone, Manager of Nuclear Fuels, Mississippi Power & Light Company, Post Office Box 1640, Jackson, MS 39205, (601) 969-2631

Shoichi Yamada, Asst. Manager of Affair Dept., Japan Nuclear Security System Co., Ltd., 1-21-17 Toranomon, Minato-Ku, Tokyo, Japan

Ichiro Yamato, Mitubishi Electric Company, Kobe chi Hyogo ku, Wadasaki, Japan

Minoru Yoshii, Officer, International Atomic Energy Agency, Wagramerstrasse 5, P.O. Box 200, A-1400, Vienna, Austria

SOUTHEAST CHAPTER

MARY S. DODGEN, CHAIRMAN
E.I. duPont de Nemours & Company
Savannah River Plant
Aiken, South Carolina

Ralph Caudle, Director of the Office of Safeguards and Security, DOE-Washington, spoke to the Southeast Region Chapter and guests about his vision for the future of safeguards. The January 27 meeting was held in conjunction with the AGNS contractors review.

The chapter is cooperating with the American Nuclear Society with plans for a 1983 joint topical meeting. John H. Ellis is serving as Local Arrangements Chairman. Tentative plans are as follows:

DATE: November 27-December 1, 1983
PLACE: Hilton Head, South Carolina
TOPIC: "Safeguards Technology: The Process *Safeguards Interface*"

Here are your opportunities for involvement:

1) Volunteer to assist John with local arrangements (registration, logistics, etc.). Contact John H. Ellis, Allied-Gulf Nuclear Services, P.O. Box 847, Barnwell, South Carolina 29812.
2) Start thinking NOW about contributing a paper. The Call for Papers will be issued before you know it. Contact Milt Campbell (Technical Papers Chairman), Exxon, Richland, Washington, or E.A. Hakkila (General Chairman), LANL.

CERTIFICATION COMMITTEE

DR. FRED TINGEY, CHAIRMAN
University of Idaho
Idaho Falls, Idaho

The October 1981 issue of Association Management, pp 103-107, has an article on Certification and Certification Programs. More *and more professional organizations are adopting certification pro*grams intended to measure excellence in the profession. Some certification programs are intended primarily to raise the skill level and knowledge of the practitioners, and others simply recognize competence. Many association members say that studying for the exams is one of the best learning experiences of their professional lives. One association requires the successful passing of nine separate examinations, most of which are so difficult that the applicant has to take a course in the subject before being able to pass the exam. In some fields professionals must be certified before they are allowed to practice. In others, prestige makes the achievement worth working for. Some employers seek practitioners who are certified. Some jobs pay the certified professional more money than the uncertified one. The problem of those electing not to be certified is also recognized. The observation is made that the intent of certification is not to downgrade the professionalism of people who choose not to be certified. But there has to be some measurement of proficiency in any profession. There's nobody better to do that than the practicing professionals.

The conclusion of the article is that one can expect to see increasing numbers of associations offering professional certifications: "The amount and complexity of knowledge necessary to practice most professions is constantly growing. As that happens, professionals have greater need for a way to let their peers and potential employers know that they have demonstrated competence in their profession".

Inquiries relative to the INMM Certification Program should be addressed to Dr. F.H. Tingey, Box 778, Idaho Falls, ID 83402.

SAFEGUARDS COMMITTEE REPORT

ROBERT J. SORENSON, CHAIRMAN
Battelle Pacific Northwest Laboratories
Richland, Washington

Last October the Safeguards Committee formed an ad hoc committee and tried something I don't believe it has done before. The idea for this new venture came about during our last meeting with the NRC's Division of Safeguards. We were discussing the recent advance notice of rule making entitled, "Material Control and Accounting Requirements for Facilities Processing Formula Quantities SSNM," (*Federal Register,* September 10, 1981, p. 45144). This advance notice affects the Category I licensees who handle strategic quantitites of high enriched uranium and plutonium.

The Safeguards Committee's interest was in providing an informal forum for industry to exchange ideas and views with the NRC. The purpose of a meeting would be to provide a better understanding of the intent of the advance notice and to receive informal comments from those affected. In other words, it would allow the NRC a chance to more fully explain the objectives and options to achieve their objectives. Similarly, the affected licensees would be able to informally provide input regarding the implementation of the MC&A advance notice of rule making.

After some intial reluctance, we went ahead. The Safeguards Committee provided the forum for this exchange and facilitated the discussion. For the convenience of those having to travel, two similar, one-day meetings were held—one on the East Coast and one on the West Coast. The meeting in Washington, D.C. was held on October 27, 1981 at the Battelle Washington Operations Office, and the meeting in La Jolla, California was held on October 29, 1981 at the office of Science Applications, Inc. (SAI). We owe a debt of gratitude to both SAI and Battelle-Washington for hosting our meetings and providing such a comfortable environment.

At the conclusion of both meetings, we requested that the participants fill out a "meeting feedback" form. We were pleased that all of the participants felt the meeting was useful. Some of the comments were:

- Very useful meeting; it gave us an opportunity to ask questions, clear interpretations, and get a better understanding of the intent of the NRC approach.
- Yes; it provided another forum to interact with the NRC staff on other than a licensee vs regulatory mode.

Another question on the meeting feedback form was: "Should the Safeguards Committee continue holding government/industry meetings?" Again, we were pleased with the unanimous favorable response. Some of the comments were:

- Yes; it helps to get several licensees in the same room with time to discuss a common problem with the NRC.
- Yes; continuing dialogue between the NRC staff and the licensees is necessary to try to meet the regulatory conditions in as cost-effective manner as possible.
- Yes; I'm particularly interested in its interaction with other government agencies.
- Yes—frequently, too; especially on such controversial issues as MC&A reform amendments.

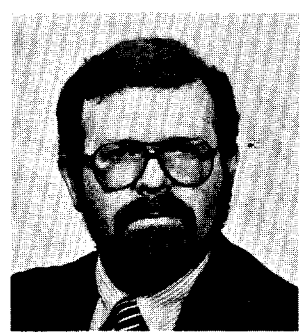
Some other interesting general comments were:

- This type of meeting helps with regulatory/industry relations and are excellent for mutual understanding.
- I like this approach—active involvement on current issues. Helps answer questions caused by new regulations.
- Keep up the good work; but be sure the Safeguards Committee is well represented.
- Maybe the Safeguards Committee should follow-up on comments and suggestions made at the meeting and prepare a report or newsletter periodically on actions taken.

If any of you readers have other comments about these meetings, please pass them along to me or another member of the Safeguards Committee. Also, if you have an idea for a similar meeting, please pass it along to one of us on the Committee.

SHEA JOINS INET

Dr. Thomas E. Shea



Dr. Thomas E. Shea recently joined the INET Corporation as Vice President for Consulting Services. Located in Sunnyvale, California, INET provides consulting services to government and industry regarding nuclear reactor safety, startup operations, maintenance and training and in domestic and international safeguards.

Shea joins INET from the IAEA's safeguards systems studies section, where he was responsible for establishing criteria and technical measures currently used in implementing IAEA safeguards, and for developing an assessment methodology used for design reviews, inspection planning and performance evaluations.

Shea has been an active member of the Institute since 1970. While in Vienna, he was instrumental in starting the Vienna Chapter, and served as Secretary before returning to the U.S.

INTRODUCTORY STATISTICS COURSE

During the week of January 11-15, 1982, eight participants attended the Introductory Course on Statistics with Applications to Special Nuclear Material Control. The course was sponsored by the INMM and hosted by the INET Corporation.

This course has evolved from the earlier version developed by John Jaech and presented once or twice per year since the late 60's. *The instructor was Dr. Gregg Dixon, INET consulting* engineer and Associate Professor of Mechanical Engineering at California State University at Northridge. Dixon previously prepared and presented a course for new IAEA staff, which provided useful background for this presentation. The course emphasized training in the basic concepts of error, identification and estimation of random and systematic uncertainties, error propagation, probability concepts, and statistical inference. Morning lectures were balanced by extensive afternoon exercises, oriented towards both facility operator applications and independent verifications by NRC, DOE and IAEA control authorities. The course materials were developed with the INMM Certification Examination in mind.

Attending the course were: Marilyn Bange, Department of Energy, Albuquerque Operations Office; Roy L. Bruce, General Electric Co., Wilmington Operations; Stephen Chin, Lawrence Livermore National Laboratory; Harvey T. Cohen, Combustion Engineering; George T. Furner, Rockwell International, Hanford Operations; Akira Maki, Power Reactor & Fuel Development Corp. (PNC), Japan; Gilbert Nelson, NRC, Region 5 Office; and Louis R. Perez, Los Alamos National Laboratory.

Tom Shea and Herman Miller of INET served as hosts and logistics coordinators.

Participants of INET Introductory Statistics Course held January 11-15, 1982 in Palo Alto, CA. First row, Furner, Perez, Bruce, Cohen, Bange and Miller; Back row, Shea, Maki, Chin, Nelson and Dixon.

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LOS ALAMOS/D.O.E. ANNOUNCE SHORT COURSES

Advanced Neutron Workshop on Nuclear Material Assay, Los Alamos, New Mexico, June 21-24, 1982. This workshop will consist of a combination of lectures and laboratory sessions on active and passive neutron assay. The lectures will cover the principles of neutron interactions in materials, neutron sources, and detectors. The laboratory sessions will be selected from topics such as neutron coincidence counting, delayed neutron measurements, photo-neutron interrogation, and pulsed neutron generators. Nuclear fuel cycle materials such as plutonium and uranium metals, oxides, and fabricated fuel rods will be assayed. The emphasis will be on understanding of the design features, measurement principles, and relative capabilities of these techniques. Because this workshop will deal with advanced concepts in neutron-based nondestructive assay, prior attendance at the Fundamentals of NDA course or equivalent experience is required. Registration is limited to 18. Reservations will be accepted after April 1, 1982.

Advanced Systems For Nuclear Materials Accounting, Los Alamos, New Mexico, August 24-27, 1982. An overview of the theory, design, and implementation of advanced materials accounting systems. The course reviews the components and structure of safeguards systems, including safeguards considerations important to process design, modeling simulation for performance evaluation, and sophisticated data analysis techniques. Examples will be drawn from operating systems and demonstration of analysis methods for nuclear materials accounting data. Registration is limited to 40. Reservations will be accepted at any time.

Fundamentals of Nondestructive Assay of Fissionable Material Using Portable Instrumentation, Los Alamos, New Mexico, October 4-8, 1982. A survey of gamma-ray and neutron nondestructive assay techniques, based upon commercially available portable instrumentation. Topics include: basic neutron and gamma-ray detection methods; gamma-ray measurements of uranium enrichment; quantitative plutonium assay using gamma-ray, neutron singles, and neutron coincidence counting methods for both plutonium and uranium samples. Although some technical background is recommended for attendees, no detailed knowledge of nondestructive assay techniques is assumed. Registration is limited to 32. Reservations will be accepted after July 1, 1982.

Gamma-Ray Spectroscopy for Nuclear Material Accountability, Los Alamos, New Mexico, December 6-10, 1982. An overview of the use of high-resolution gamma-ray spectroscopy in the nondestructive assay of plutonium and uranium in various materials. The course emphasizes laboratory experience, but includes a number of formal lectures. Topics include: general techniques of high-resolution spectroscopy, transmission correction factors and absorption-edge densitometry. Demonstrations of automated systems are given. Because this course deals with advanced concepts in gamma-ray based nondestructive assay, familiarity with nuclear instrumentaton and prior attendance at the Fundamentals NDA course or equivalent experience is strongly recommended. Registration is limited to 24. Reservations will be accepted after September 1, 1982.

Brochures with registration information will be available from Los Alamos National Laboratory, Mail Stop 551, P.O. Box 1663, Los Alamos, NM 87545, well in advance of the first school.

DETERMINATION OF Pu AMOUNT IN A WASTE CARTON BY GAMMA-RAY MEASUREMENT

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ABSTRACT

The amount of Pu-239 in a waste carton is determined by gamma-ray measurements. The measuring deviations caused by non-uniform distirubtion in the carton and by the large volume are minimized by rotating and scanning the object. Attenuation corrections by two methods were studied and compared: (1) the use of an external gamma-ray source to measure the attenuation as a function of position in a carton, and (2) the estimation of attenuation factor on the basis of weight of the carton and the density of the matrix. Calibration standards were made with 4 different types of matrix material and locations for well measured sources containing from 3 to 80 mg of Pu. Using a NaI(Tl) scintillation detector, and accumulating the activity in the 360-470 KeV region for 400 to 1,000 seconds, Pu content can be determined to within about 50% at 3 mg and about 10% at 80 mg level in a 17 liter cardboard carton.

1. INTRODUCTION

Pu bearing solid wastes are of necessity generated at the Pu handling laboratory in the Japan Atomic Energy Research Institute (JAERI). The waste must be placed into storage in distinction from β, γ bearing wastes, when the quantitative measurement of Pu is needed for the control of its amount in a storage site. On the other hand, the measurement is also necessary to determine the amount of loss of a process, and to account for all plutonium(1-4).

Several methods concerning nondestructive assay of Pu have been proposed and applied to various purposes: passive γ-ray assay (5-19), passive and active neutron assays (20-23), and calorimetric assay (24,25). Among them, the γ-ray measuring method is rapid, sensitive to small amounts, and considered to be suitable for the determination of Pu amounts in waste containing less than a gram quantity. The method is, however, often limited by the γ-ray attenuation of Pu in a matrix material, and by a "bulky source" of γ rays. The present work is to develop a reliable and convenient γ-ray technique for the determination of Pu-239 weight in waste containing several kinds of other materials.

2. EXPERIMENTAL

2.1. Materials

Pu metal (NBS-949d) was dissolved in 1 M H_2SO_4 solution. An aliquot of the solution was poured into a polyethylene vial with a wall of 0.4 mm thickness. The vial was then sealed up in a polyvinylchloride (PVC) bag of 0.3 mm thickness. Seven γ-ray sources containing 1.0, 2.0, 5.0 mg of Pu and 20.0 mg (four packs) were prepared for calibrating. The isotopic abundances of Pu-239, Pu-240 and Pu-241 in the sources were 97.65, 2.3, and 0.07 atom %, respectively, in January, 1980. A carton for containing radioactive solid wastes is the standard container described in Japan Industrial Standards, JIS-Z-4902: top 280, bottom 230 mm in diameter, effective height 350 mm and effective volume 17 liters. This is made of 0.5 mm thick cardboard. A large polyethylene bag of 0.05 mm thickness is fixed inside it with adhesive tape. Combustible and incombustible wastes are contained in red and white colored cartons, respectively.

2.2. Gamma-ray measurement

The γ ray of Pu-239 in the 360-470 KeV region (or 320-470 KeV) is utilized in this work, as seen in Fig. 1. The activity of Pu in a carton is measured in a scanning system as shown in Fig. 2. A NaI(Tl) scintillation detector (76 mm d. x 76 mm thickness) is located as shown. The carton is rotated at the rate of one rpm and driven up and down at the rate of more than one time during a measurement. When an external source is used, a 10 μCi point source of Cs-137(Ba-137m) is fixed at the opposite side of the carton to the detector. The γ-ray (620-750 KeV) collimated with a lead block (1 mm diam. x 50 mm length) passes through the carton during scanning. The Pu amount in a carton was determined from the data obtained by five time measurements.

3. RESULTS AND DISCUSSION

3.1. Geometrical influences

A carton to be measured is a bulky γ-ray source. Further, the uniform distribution of Pu in it cannot be expected. In this case, a scanning measurement will be needed to minimize the measuring deviations. A carton containing a known amount of Pu was measured in the system described in Fig. 2, in order to make sure of the geometrical influences. Four packs of Pu having 20 mg each were set in arbitrary positions, Nos. 1-9 shown in Fig. 3. The values obtained by the measurements were compared with that of the center position, No. 2. The result is also given in Fig. 3. The Pu amount can be determined to within 25% by the scanning technique.

3.2. The first method for the correction of γ-ray attenuation.

The γ-ray of Pu is very sensitive when passing through material. Correction for its attenuation was estimated by the use of an external source, Cs-137. Three energy regions are always observed at the same time in the technique; the γ-ray activities in the 320-470 KeV (the first) region and the 620-750 KeV (the third) are accumulated for Pu-239 and for Cs-137, respectively. The value to be obtained for Pu, however, is overestimated because of the compton tail of Cs-137. It is corrected by accumulating the activity in the 470-620 KeV (the second) region.

3.2. (1) Calibration curve

The γ-ray activities in the three regions are accumulated at the same time in the scanning system for a live time of 1,000 seconds, in order to get the equivalent weight of Pu by its activity. The net value of Pu activity was substantially equal to ($\underline{A}$ - 2$\underline{B}$), where $\underline{A}$ and $\underline{B}$ represent the activity value accumulated in the first and second regions, respectively. Pu sources were hung in air with a spiral wire, to make the attenuation negligible. The position was approximately at the center of the carton, No. 2 in Fig. 3. A calibration curve was made by the use of 1.0, 2.0, 3.0, 5.0, 8.0, 20, 40, 60 and 80 mg sources of Pu, as seen in Fig. 4. The values obtained from the third energy region (Cs-137) are always constant in this case.

3.2. (2) Correction factors

Correction factors for the determination of Pu weight in matrix materials could be obtained on the basis of the external source. A known-amount Pu source was set in a carton filled with a matrix material, and measured by scanning. The activities in the three energy regions were accumulated at the same time for 1,000 seconds. When the values obtained from the first and second regions are dealt with, $\underline{A}'$ and $\underline{B}'$ respectively, the net activity to be corrected can be expressed as,

$$(\underline{A}'f_1 - \underline{B}'f_2)_{Matrix} = (\underline{A} - 2\underline{B})_{Air}$$

where f_1 and f_2 represent the coefficients for the attenuation of γ-rays in the first and second region, respectively. The γ-rays of the external source are also attenuated by the matrix. I/I_o represent the intensity ratio for a given matrix, where I and I_o are the values obtained by accumulating the activities in the third region passing through the matrix and air, respectively. As typical matrix material, paper, rag, PVC-sheets and sand were selected and packed in cartons, respectively. They had densities in the range of 0.1-1.5 g/cm^3. Then, several sources of known-amounts of Pu were set one by one at the core in one of the cartons, and the activities in the three regions were measured by scanning, in order to get the appropriate coefficients, f_1 and f_2. In Fig. 5, the values obtained are plotted vs. I/I_o for the external source.

When an intensity ratio, I/I_o of the external source gives a value of less than 1 for a carton containing Pu, the correction factors f_1 and f_2 can be obtained from the curves in Fig. 5, for the values $\underline{A}$ and $\underline{B}$ accumulated in the first and second regions, respectively. Thus, the activity of Pu in the carton is expressed as,

$$\text{Net activity of Pu} = \underline{A}f_1 - \underline{B}f_2$$

In the case of $I/I_o = 1$, the value, ($\underline{A}$ - 2$\underline{B}$) is obtained from Fig. 5. The equivalent weight of Pu for the corrected activity is given on the calibration curve in Fig. 4.

3.2. (3) Verification of the correction technique

The reliability of the techniques described above was ascertained with the use of 3.0 and 80 mg sources of Pu. Each source was set at the core in a carton packed with paper, rag, PVC-sheets or sand, and measured in the scanning system. The values obtained from both are generally reasonable, as seen in Table 1. Although even a carton having the density of 1.5 g/cm^3 can be assayed for Pu by the correction technique, most cartons arising from the laboratory are of low-to-medium density, 0.1-0.5 g/cm^3. The determination of Pu weight for these will be relatively easy. The values obtained when using the 3.0 mg source, however, have large deviations regardless of the density of matrix material. Three mg weight of Pu may be the lower limit for the scanning system.

3.2. (4) Measurements of waste cartons

Seven cartons containing incombustible and combustible wastes were assayed for Pu in the scanning system. The obtained results are shown in Table 2. Densities of the incombustible and combustible are about 0.3 and 0.2 g/cm^3, respectively. Attenuation of the external γ-ray occurs in all of the cartons. The I/I_o values are about 0.6 for the incombustible and about

0.8 for the combustible. Therefore, corrections of 30 to 10% are needed for the γ-ray activity of Pu.

The net γ activities of Pu given in serial Nos. 2-4 are low. The obtained values correspond to about 1 mg of Pu on the calibration curve in Fig. 2, though these are not reliable because of the large standard deviations. The cartons were classed as containing <3 mg of Pu. Serial No. 5 is a waste arising from an Am-241 handling glove box. It was clear that the waste was barren of Pu, though it gave a pseudo value under the measuring conditions. Am-241 emits a few γ-rays of weak intensity in the 330-340 KeV region in addition to the line at 59 KeV (26,27). Fig. 1 shows that Am-241 γ-rays may influence the Pu assay if region 1 is 320-470 keV. Subsequently the region 360-470 KeV, was used.

3.3. The second method for the correction of γ-ray attenuation

The γ-ray of Pu is attenuated when passing through the material in a carton. It is essential for application to routine measurements that the reduced γ-ray be corrected by a simple technique. Although the matrix is inhomogeneous, it is considered to have an average effect in the rotating and up-and-down motion. On this assumption, correction on the basis of the weight of a carton, that is, "density", was investigated.

3.3. (1) Calibration curve

The energy region to be observed was narrowed down to 360-470 KeV in order to avoid the influence of the 330-340 KeV rays emitted by Am-241. The γ-ray activities of Pu and the room background are each accumulated for a live time of 400 seconds in the scanning system. The value, (A - B) is the net activity of Pu, where A and B represent the integral activities of Pu and the background in the 360-470 KeV region, respectively. The value, B was $\sim 2.15 \times 10^3$ counts/400 sec in the room used. It is substantially constant and hardly influenced because of leaving a space of more than 100 mm between the detector and carton, even when a carton having the density of 1.5 g/cm^3 is measured.

A calibration curve for Pu weight versus net γ activity is made by the use of the sources containing 1.0, 2.0, 5.0, 8.0, 20, 40, 60, and 80 mg of Pu, as shown in Fig. 6. The sources in this case were also hung in the air with a spiral wire in the position of the core in a carton.

3.3. (2) Correction factor

A correction factor for the determination of Pu weight in the matrix is defined as

$$f = \frac{\text{Net } \gamma\text{-ray activity of Pu passing through the air}}{\text{Net } \gamma\text{-ray activity of Pu passing through the matrix}}$$

The activities from the sources having 20, 40, 60 and 80 mg of Pu were measured in the air, and then in one of the cartons containing paper, rag, PVC-sheets and sand. From the results obtained, a curve concerning the defined factor versus matrix density is made, as shown in Fig. 7.

By weighing a carton to be assayed for Pu, a correction factor, f, is obtained from the curve in Fig. 7, while an activity value, A is also obtained by accumulating the activity from the carton for 400 seconds. Thus, the corrected value, (A - B)f can be obtained as the net activity of Pu. The Pu weight for the carton is consequently determined from the calibration curve in Fig. 6.

3.3. (3) Verification of the correction technique

The technique described above was ascertainted by measuring the activity from a known-amount source of Pu set in several kinds of matrix material. Paper, rag, PVC-sheets and sand were selected as matrix material, and packed in cartons, respectively. They were weighed to get their densities. The corresponding f values are shown on the curve in Fig. 7. The sources, having 3.0 and 80 mg of Pu were set at the core in each of the cartons. They were measured in the scanning system. As seen in Table 3, reasonable amounts of Pu are determined by the technique, while they are reduced in the case of no correction. The result also shows that 3 mg of Pu in a carton should be the lower limit of determination in this method as in the previous method.

Compared to the previous, the present method is very similar in reliability and sensitivity, and it is simpler and faster. These factors will play an important role in the routine work.

3.3. (4) Measurements of waste cartons

The seven cartons assayed in the previous method were again assayed for Pu weight by the present method. The results obtained are given in Table 4. The activities from serial Nos. 2-5 are nearly equal to the room background, 2 x 10^3 counts for 400 seconds. These cartons are considered to be easy to determine, for their having densities in the range of 0.1 - 0.5 g/cm^3. The cartons with the wastes containing less than 3 mg of Pu were also measured. In the previous measurement, the No. 5 carton gave a spurious result. The γ-ray in the 320-340 KeV region from Am-241, however, is cut off in this case so that its influence is eliminated from the measuring region of Pu, as seen in Table 4. The amounts of Pu in Nos. 1, 6 and 7 are very similar to those obtained in the previous case.

CONCLUSION

Miscellaneous wastes are contained in a waste carton arising from the Pu handling labortory in JAERI. The determination of the contained Pu weight is difficult because of geometrical and attenuation factors. It was required to develop a technique for routine application. The γ-ray from Pu-239 in a carton is often attenuated with the matrix. The measurement, however, must always be reliable. In the present work, two methods have been studied for the use of NaI(Tl) scintillation detectors.

In the first method, an external source is used for correction of attenuation of the Pu gamma ray. The waste carton is always scanned by the beam of the external source during the measurement. By measuring a calibrating source of Pu set in four different matrix materials, it is ascertained that the external source is very useful as standard. The external source is also convenient to detect any trouble with the measuring apparatus. In this method, the whole energy region of the Pu γ-ray (320-470 KeV) was employed for evaluation of the amount of Pu in a carton. However, the weak gamma ray from Am-241 falls into this region. It can be quite significant for high-burnup Pu, and the intensity changes with time (Pu-241 decay). To avoid this influence, the energy region must be narrowed to 360-470 KeV. Although the activity of about 30% in the 320-470 KeV cannot be utilized for the measurement, setting to the narrower region was necessary in order to get reliable data.

In the second method, the correction for attenuation is based on the matrix density measured by weighing. Most of the wastes in the glove boxes of the laboratory are packed in small cardboard cartons (100 mm diam. x 240 mm height). Others, such as neoprene gloves, are put into polyethylene bags like an oval Rugby football. They are sealed up in PVC bags. Then, several packs of them are contained in a waste carton. The content is never homogeneous in the carton, but they are filled to the top. Before the γ-ray measurement of a carton, it is necessary to ascertain whether it is filled up. The checkup is, however, easy from the outside since they are made of thin cardboard. The method is simpler and faster. The reliability is quite similar to that of the first method. Consequently, it is considered to be suitable for routine use. By comparing it with the first method, it will be more verified in succeeding measurements.

ACKNOWLEDGEMENT

The author wishes to thank Mr. K. Gunji in Japan Atomic Energy Research Institute for the collaboration with a mass spectrometric analysis of the Pu sample used.

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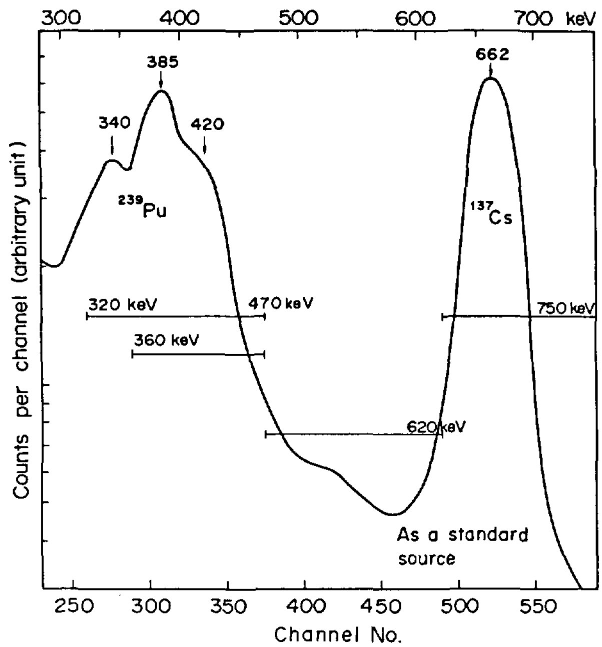


Fig. 1 γ ray spectrum of ^{239}Pu and ^{137}Cs

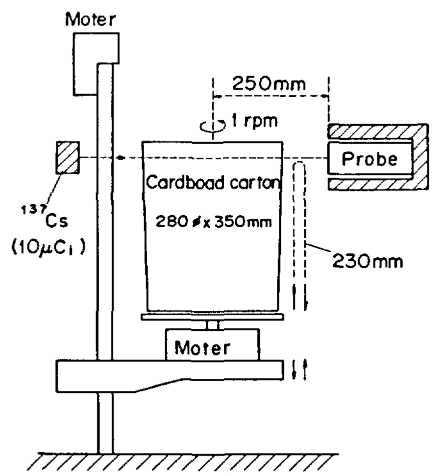
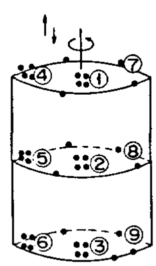


Fig. 2 Schematic view of Pu assay system



Center	Circumference	
In the block	In the block	At random
① 0.74 ± 0.03	④ 0.84 ± 0.01	⑦ 0.81 ± 0.01
② 1.00	⑤ 1.11 ± 0.01	⑧ 1.12 ± 0.01
③ 0.77 ± 0.01	⑥ 0.80 ± 0.01	⑨ 0.82 ± 0.01

Four sources containing each 20mg of Pu are set on one of the positions, No. 1-9, and measured in the scanning system. The data obtained from the positions are compared with that of the core position, No. 2.

Fig. 3 Influences of waste-carton bulk and Pu maldistribution on γ-ray measurement

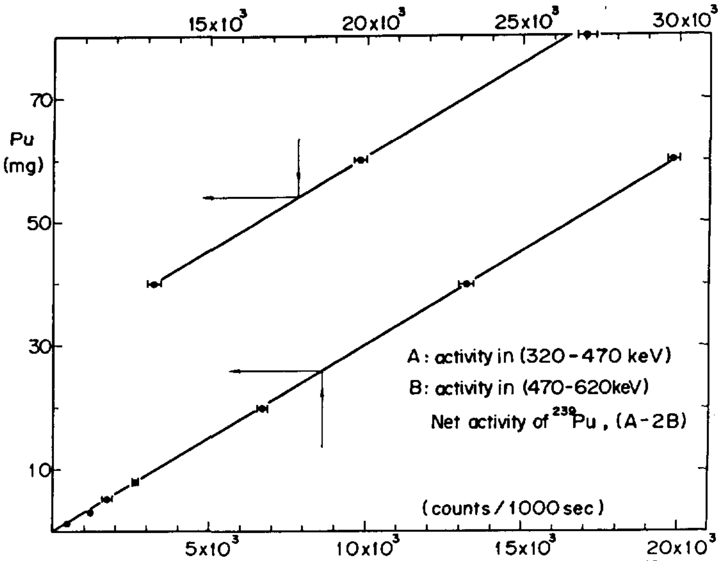


Fig. 4 Calibration curve – Pu weight vs. net γ activity of ^{239}Pu in 320 – 470 keV region

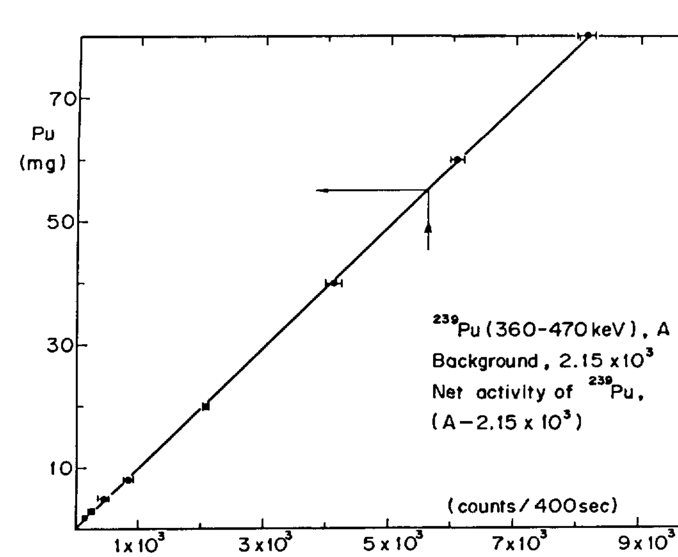


Fig. 6 Calibration curve – Pu weight vs. net γ activity of ^{239}Pu in 360 – 470 keV region

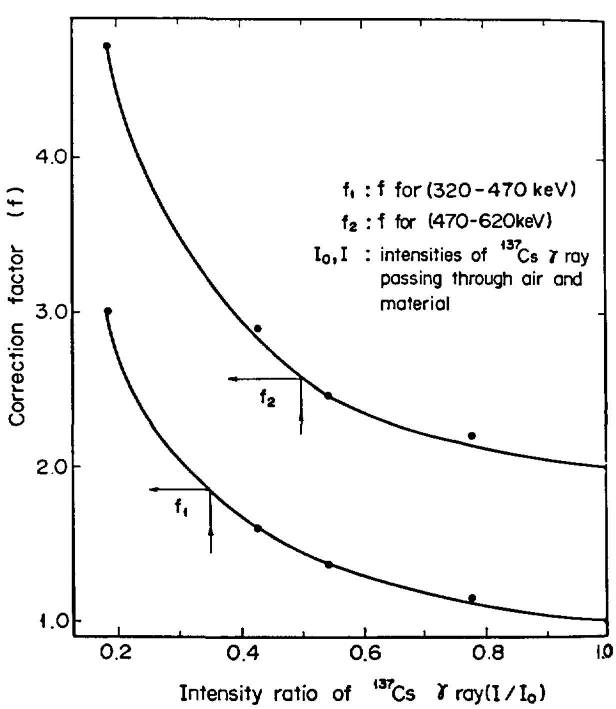


Fig. 5 Correction factors for the influence of matrix material

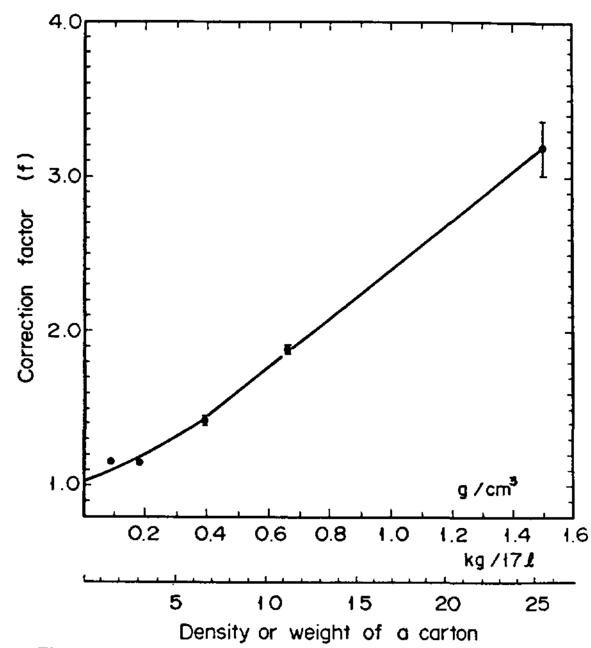


Fig. 7

Correction factor for the influence of matrix material

Table 1 Determination of Pu amounts in matrix materials in the use of 3.0 and 80.0 mg sources

Pu (mg)	Matrix*	Density (g/cm^3)	^{137}Cs I/I_0	^{239}Pu, A	C.F.**, f_1	Background, B	C.F., f_2	Pu found $Af_1 - Bf_2$	Pu found (mg)
3.0	Paper	0.09	0.89	$(14.4 \pm 0.3)\times10^3$	1.06	$(6.67 \pm 0.01)\times10^3$	2.05	$(1.6 \pm 0.3)\times10^3$	4.9 ± 0.9
3.0	Rag	0.18	0.76	$(13.1 \pm 0.2)\times10^3$	1.15	$(6.4 \pm 0.1)\times10^3$	2.16	$(1.2 \pm 0.3)\times10^3$	3.5 ± 0.9
3.0	PVC-sheets	0.39	0.55	$(11.4 \pm 0.1)\times10^3$	1.37	$(5.93 \pm 0.08)\times10^3$	2.46	$(1.0 \pm 0.2)\times10^3$	3.0 ± 0.6
3.0	Sand	1.50	0.19	$(9.3 \pm 0.1)\times10^3$	2.86	$(5.62 \pm 0.01)\times10^3$	4.60	$(0.7 \pm 0.3)\times10^3$	2.0 ± 0.8
80.0	Paper	0.09	0.89	$(36.9 \pm 0.6)\times10^3$	1.06	$(6.97 \pm 0.01)\times10^3$	2.05	$(24.8 \pm 0.6)\times10^3$	75 ± 2
80.0	Rag	0.18	0.76	$(35.5 \pm 0.9)\times10^3$	1.15	$(6.74 \pm 0.06)\times10^3$	2.16	$(26 \pm 1)\times10^3$	79 ± 3
80.0	PVC-sheets	0.39	0.55	$(30.5 \pm 0.1)\times10^3$	1.37	$(6.15 \pm 0.04)\times10^3$	2.46	$(26.6 \pm 0.2)\times10^3$	80 ± 0.6
80.0	Sand	1.50	0.19	$(17.9 \pm 0.3)\times10^3$	2.86	$(5.78 \pm 0.03)\times10^3$	4.60	$(24.6 \pm 0.9)\times10^3$	74 ± 3

Gamma-ray activity (counts/1000 sec)

* Packed in 17 l carton
** Correction factor

Table 2 Determination of Pu amounts in waste cartons

Waste carton* Serial No.	Density (g/cm^3)	^{137}Cs I/I_0	^{239}Pu, A	C.F., f_1	Background, B	C.F., f_2	Pu found $Af_1 - Bf_2$	Pu found (mg)
Incombustible								
1	0.25	0.69	$(20.3 \pm 0.1)\times10^3$	1.22	$(7.0 \pm 0.1)\times10^3$	2.25	$(9.0 \pm 0.3)\times10^3$	27 ± 1
2	0.26	0.60	$(11.8 \pm 0.1)\times10^3$	1.30	$(6.35 \pm 0.03)\times10^3$	2.37	$(0.3 \pm 0.2)\times10^3$	<3
3	0.46	0.53	$(11.0 \pm 0.05)\times10^3$	1.39	$(6.2 \pm 0.1)\times10^3$	2.51	$(0.3 \pm 0.3)\times10^3$	<3
4	0.20	0.69	$(13.1 \pm 0.1)\times10^3$	1.22	$(7.0 \pm 0.1)\times10^3$	2.25	$(0.2 \pm 0.3)\times10^3$	<3
5 ^{241}Am waste	0.26	0.66	$(15.6 \pm 0.1)\times10^3$	1.23	$(6.5 \pm 0.1)\times10^3$	2.28	$(4.4 \pm 0.3)\times10^3$	(13)
Combustible								
6	0.12	0.80	$(16.4 \pm 0.1)\times10^3$	1.12	$(7.0 \pm 0.1)\times10^3$	2.12	$(3.5 \pm 0.2)\times10^3$	10.5 ± 0.6
7	0.17	0.76	$(25.3 \pm 0.2)\times10^3$	1.15	$(7.2 \pm 0.01)\times10^3$	2.15	$(13.6 \pm 0.2)\times10^3$	41.0 ± 0.6

Gamma-ray activity (counts/1000 sec)

* Packed in 17 l carton

Table 3 Determination of Pu amounts in matrix materials in the use of 3.0 and 80.0 mg sources

Pu (mg)	Matrix* Density (g/cm^3)	C.F.** f	Pu γ-ray activity (360-470KeV region) A (counts/400 sec)	Pu found (A-B***)f (mg)	Without correction, A-B (mg)
3.0	Paper 0.09	1.08	$(2.43 \pm 0.03) \times 10^3$	$(3.0 \pm 0.4) \times 10^2$ 3.0 ± 0.4	2.5
3.0	Rag 0.18	1.20	$(2.35 \pm 0.06) \times 10^3$	$(2.4 \pm 0.8) \times 10^2$ 2.1 ± 0.7	2.0
3.0	PVC-sheets 0.39	1.48	$(2.28 \pm 0.03) \times 10^3$	$(1.9 \pm 0.6) \times 10^2$ 1.9 ± 0.6	1.1
3.0	Sand 1.50	3.15	$(2.32 \pm 0.03) \times 10^3$	$(5 \pm 1) \times 10^2$ 5 ± 1	1.5
80.0	Paper 0.09	1.08	$(9.4 \pm 0.3) \times 10^3$	$(7.8 \pm 0.3) \times 10^3$ 77 ± 3	71
80.0	Rag 0.18	1.20	$(9.2 \pm 0.1) \times 10^3$	$(8.5 \pm 0.1) \times 10^3$ 83 ± 1	69
80.0	PVC-sheets 0.39	1.48	$(7.9 \pm 0.1) \times 10^3$	$(8.5 \pm 0.1) \times 10^3$ 83 ± 1	56
80.0	Sand 1.50	3.15	$(4.65 \pm 0.02) \times 10^3$	$(7.87 \pm 0.04) \times 10^3$ 77.5 ± 0.4	25

* Packed in 17 l carton
** Correction factor
*** Room background in 360-470 KeV region, $(2.15 \pm 0.03) \times 10^3$ counts/400 seconds

Table 4 Determination of Pu amounts in waste cartons

Waste carton* Serial No.	Density (g/cm^3)	C.F. f	Pu γ-ray activity (360-470KeV region) A (counts/400 sec)	Pu found (A-B**)f	(mg)
Incombustible					
1	0.25	1.29	$(4.2 \pm 0.1) \times 10^3$	$(2.6 \pm 0.1) \times 10^3$	25.5 ± 0.1
2	0.26	1.31	$(2.15 \pm 0.04) \times 10^3$	Room background	< 3
3	0.46	1.57	$(2.10 \pm 0.04) \times 10^3$	Room background	< 3
4	0.20	1.23	$(2.32 \pm 0.02) \times 10^3$	$(0.21 \pm 0.04) \times 10^3$	< 3
5	^{241}Am waste 0.26	1.31	$(2.24 \pm 0.02) \times 10^3$	$(0.12 \pm 0.05) \times 10^3$	< 3
Combustible					
6	0.12	1.13	$(2.99 \pm 0.01) \times 10^3$	$(0.95 \pm 0.04) \times 10^3$	9.1 ± 0.4
7	0.17	1.18	$(5.5 \pm 0.1) \times 10^3$	$(3.9 \pm 0.1) \times 10^3$	39 ± 1

* Packed in 17 l carton
** Room background, $(2.15 \pm 0.03) \times 10^3$ counts/400 seconds

EMPLOYEE AVAILABILITY IMPROVEMENTS THROUGH PERSONNEL CONTROL SYSTEM DESIGN

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ABSTRACT

The design of the personnel control system at a nuclear facility can have a significant influence on the availability of employees at their work station. This paper presents a methodology--based on a stochastic network approach--which can be used to quantify the effect of changes in the design of a personnel control system on employee availability. To illustrate the technique, a model of the personnel control system for the DOE's Fuels and Materials Examination Facility on the Hanford Reservation near Richland, Washington has been constructed using the Q-GERT network simulation language. Monte Carlo simulations of personnel flow (with queueing) within the model network were carried out for a base case and for specific modifications to the base case to determine the impact of design changes in the personnel control system on certain worker performance measures such as worker availability. Results of these simulations show that certain modifications to the personnel control system entailing staggering of shifts and improvements and additions to existing hardware can lead to significant savings in yearly costs.

INTRODUCTION

The amount of time that an employee of a nuclear facility must spend in getting to and from a work station can have a substantial impact on his or her availability at that station. Clearly, the more time spent in changerooms and personnel portals, the less time the employee is available to perform the job at his work station. This paper presents an analytical approach to quantifying the effect of changes in the design of the personnel control system--procedural changes as well as changes in hardware--on employee availability.

The approach involves first the development of a graphical model of the flow of personnel within the facility. Next, to provide a computer simulation of personnel flow, the graphical model is translated into a form that can be handled by the computer. Finally, experiments (computer simulations) are conducted using the computerized model to estimate certain performance measures as a function of various design configurations.

The specific objective of this work was to provide information to engineers at the Hanford Engineering Development Laboratory who are responsible for the design of the Fuels and Materials Examination Facility (FMEF). The FMEF is a Department of Energy facility under construction on the Hanford Reservation near Richland, Washington. The FMEF will be used to fabricate nuclear test fuels and to examine irradiated materials and spent fuels in support of operations at the colocated Fast Flux Test Facility. Because of the FMEF function, the necessity for having a personnel control system that promotes safety and security is self-evident.

The availability of FMEF personnel was selected as the primary system performance measure. For purposes of this study, "availability" is defined as the total time that an employee is available at his or her work station--exclusive of time spent in portals, on break, or in transit, etc. Secondary performance measures, herein referred to as "Queueing Statistics", include estimates of the average and maximum times and the average and maximum numbers of personnel at potentially congested locations within the FMEF.

The next section provides a description of the model that was used to represent the FMEF. The model description is followed by a discussion of the results of the computer simulations. Finally, a section is included that highlights the results of this study and indicates the general applicability of this approach to the design of other personnel control systems.

MODEL DESCRIPTION

The network "language" which was used to construct the model is Q-GERT[1]. This language is particularly well suited to accommodate the complex queueing situations that can be present in a personnel flow system. In addition to the network symbology, Q-GERT also provides a Monte Carlo simulation capability. To use this capability, each of the network symbols is translated into a computer data statement. These data statements are then read by the Q-GERT analysis program which, in turn, simulates the flow of personnel through the facility.

A cutaway view of the FMEF is shown in Figure 1. The facility consists of six levels and an entry wing. Access to the facility grounds is through the Perimeter Guard Station (PGS). For purposes of this study, FMEF employees were placed in three categories: fuel fabrication (FUEL), examination (EXAM), and administration (ADMIN). The FUEL workers use the upper three levels, the EXAM workers use the lower three levels and the ADMIN workers use the entry wing.

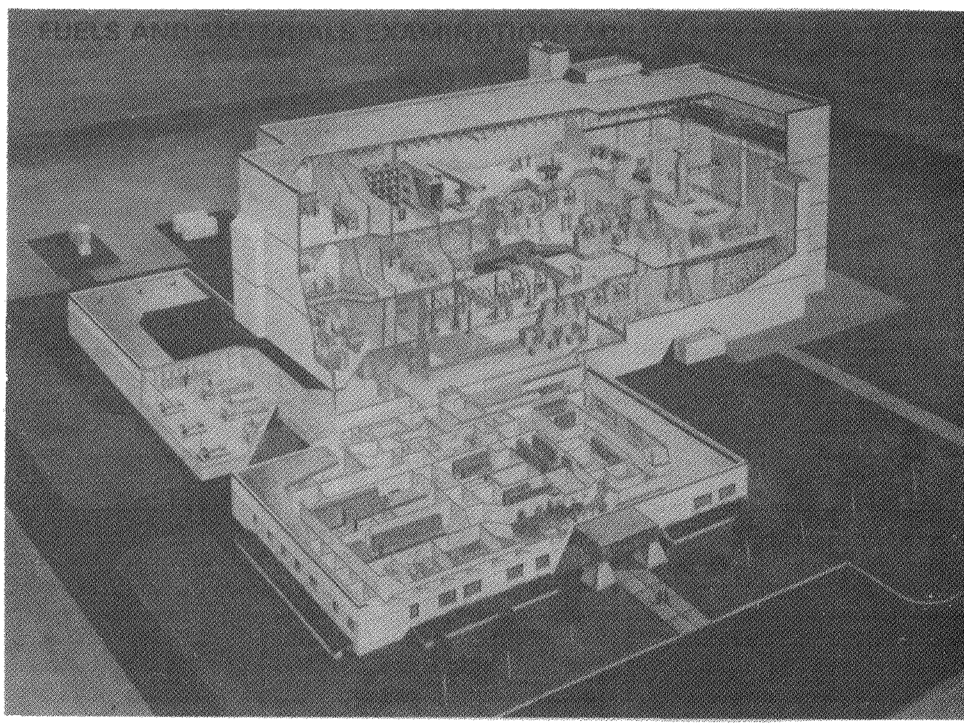

Figure 1. Cutaway View of the FMEF

Because of its complexity, an illustration of the actual FMEF Q-GERT network is not warranted in this abbreviated discussion. A greatly simplified representation of the flow of personnel within the FMEF is, however, shown in Figure 2. The overall network consists of network consists of four interlinked subnetworks, one for each of the three employee categories and a fourth representing flows that are common to all three employee categories. The "common" subnetwork contains the following elements: the employee arrival generation function, the PGS, the facility grounds, and the lunchroom. The arrival generation function simulates the arrival of employees. Each arriving employee is assigned attributes corresponding to the time of day, category of employee, and destination. Arriving workers pass through the PGS access control system that consists of three automated portals, a package X-ray unit, and a bypass portal. Employees place their lunch buckets on the package X-ray unit and then pass through one of the automated portals. If all of the automated portals are busy, the employee waits before dropping off his lunch. Occasionally the portal will refuse to pass a person. That person must then go to the bypass portal to be checked by a guard.

[1] "GERT" is an acronym for Graphical Evaluation and Review Technique. The prefix "Q" indicates that queueing systems can be modeled. Q-GERT is documented in [1].

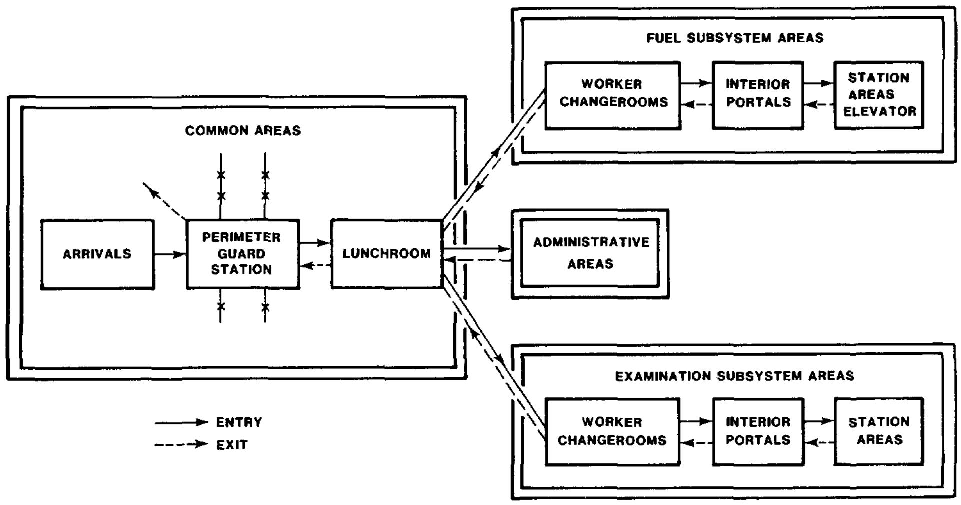

Figure 2. Representation of the Personnel Flow Within the FMEF

After passing through a portal, the employee walks through the Entry Wing. The employees drop off their lunches in the lunchroom. Their paths then divide according to employee category. Each employee then travels to his work area. Personnel leave their work areas for two breaks, for the lunch break, and at the end of their shift. At quitting time employees pick up their lunch buckets and exit through the PGS.

The FUEL Workers subnetwork includes separate changerooms for male and female employees, an access portal control system, a personnel elevator, keycard doors, and bathrooms. FUEL Workers must pass through changerooms and don shoe covers, a smock, and caps before entering the hardened shell of the building through the portal system. Changerooms are large enough to accommodate all FUEL Workers simultaneously. The access control portal system has two automated portals and a bypass portal. After entering the shell, Fuel Workers travel to their work station floor using a personnel elevator. Workers on levels 4 and 5 then pass through a keycard door to get to their work stations.

Once off the elevator and through the keycard door, the employee is considered to be at his or her work station. Personnel remain on station until they need to use the restroom, go on a break, or leave at the end of their shifts. The reverse path is used when leaving (through the keycard doors, down the elevator, out the portals, and through the changerooms). Twenty percent of the FUEL Workers spend their ten minute breaks in the FUEL Worker changerooms. At the end of the day, twenty percent of the FUEL Workers take showers in the changerooms.

The elevator system consists of a car that services the upper four levels. Each of these levels has a call button and a monitor that indicates the direction in which the car is moving. The car itself contains dispatching buttons that passengers push to direct the car. The floor size of the car (100 sq. ft.) limits the capacity of the car to twenty people. An electric eye causes the car door to close after the last person enters. The door opens or closes in three seconds, and the car speed is 200 ft/min.[1]

The EXAM Workers subnetwork consists of separate changerooms for male and female employees, an access portal control system, work station areas, and bathrooms. EXAM Workers must pass through changerooms to pick up lab coats before entering into the building shell through the portal system. Changerooms can accommodate all workers simultaneously. The access control portal system for EXAM Workers has one automated portal and one bypass portal. Portals are monitored by guards in the Interior Guard Station. Once inside the shell, employees take the stairs to their work stations. The EXAM Workers proceed to one of 12 work station areas. Twenty percent of the EXAM Workers spend their ten minute breaks in the EXAM changerooms. A subgroup of EXAM Workers put on shoe covers, smocks, and caps, and go to work in equipment repair rooms. These workers pass through an additional set of changerooms. It is assumed that time in the changerooms varies between 3 and 8 minutes with a mean of 5 minutes.

The ADMIN Workers subnetwork consists of work stations (offices) and restrooms. Transit time is the only delay for ADMIN Workers going to their work station. The offices in the Entry Wing are not concentrated in any one area. Availability is measured from the time workers reach their offices.

[1]Elevator specifications [2] developed by the Architect/Engineer served as a basis for these assumptions.

ADMIN Workers remain on station until they need to use the restroom (located in the FUEL Worker changerooms), go on a break, or leave. They pick up their lunches in the lunchroom during lunch but spend the lunch break in their offices. They are not counted in the statistics for number in the lunchroom during lunch.

The FMEF workday consists of three 8½ hour shifts, with a 30-minute overlap between shifts. The majority of the 276 personnel work during the first shift. The day shift begins at 7:30 a.m., the swing shift starts at 3:30 p.m., and the graveyard shift begins at 11:30 p.m. A shift includes two 10-minute breaks and a 30-minute lunch break. FUEL and EXAM Workers go to the lunchroom for all breaks, and ADMIN Workers stay in their office areas. The sequence of arrival times was modelled as an inhomogenous Poisson process. Starting with an arrival rate of 0 at 7:00 a.m., the rate peaks at 7:15 and drops linearly to 0 by 7:30 a.m.

There are three portal systems in the FMEF, the first at the Perimeter Guard Station and the other two inside the Entry Wing at the Interior Guard Station, one each for the FUEL and EXAM Workers. There are three automated portals in the PGS portal system. At the Interior Guard Station there is one automated portal for the EXAM Workers and two for the FUEL Workers. Each portal system includes automated portals and a bypass for workers who are rejected by the automated portals. Normally, workers pass through one of the automated portals that contain identification units and contraband detectors. Average Type I error (i.e., false rejection by a device) rates are assumed-- based on experience with similar equipment--to be 2% for the identification units and 1% for the contraband detectors.

Employees who fail an identification test leave the portal and go to the bypass portal where they are checked by a guard (the FUEL and EXAM employees' bypass portals are manned by guards from the Interior Guard Station). If the employee passes the identification test but fails the contraband test, the guard on duty decides whether to reject or re-test that person. The guard will re-test workers 80% of the time. Rejected workers are sent to the bypass portal. During a retest, the worker attempts to pass through the portal again. Employees pass the retest 90% of the time. If they fail the retest, they go to the bypass portal. The average time in the bypass portal is assumed to be 1 minute.

All workers anticipate shift changes (lunch, breaks, and quitting time). Workers attempt to be at the lunchroom or break areas when the lunch or break time begins and to be out of the Entry Wing by quitting time. There are six sets of restrooms, including separate facilities for men and women, represented in the model. Restroom breaks from work stations during work periods are modelled. The configurations of the restrooms were taken from the Architect/Engineer blueprints.

SIMULATION RESULTS

There were two basic objectives for the FMEF personnel flow study:

- Measure availability (by employee category) in the base case personnel control system and discover the sources of unavailability, and
- Examine several modifications to the base case to determine if these modifications improved or lowered worker availability.

A secondary objective was to monitor the congestion at portals, changerooms, and the lunchroom. There were four sets of decision variables in the study:

- Number and processing time of automated portals at the three portal systems,
- Lunch time rules for the three types of employees,
- Shift starting time for the three categories of personnel, and
- Floor levels serviced by the elevator.

For each modification, 10 weeks of data were recorded, resulting in 10 observations for each performance variable. FUEL, EXAM, and ADMIN availabilities were computed for the base case to within plus or minus 1 minute/day[1]. This represented an upper bound on cost uncertainty of $35 K/year[2]. The average availability for the three categories of employees and the facility weighted average[3] is shown in Figure 3. The areas enclosed by the rectangles, which correspond to different employee categories, represent the number of employees in each category. The maximum availability possible is 460 minutes, the time remaining when 50 minutes (breaks) are subtracted from 8½ hours of shift time. The ADMIN employees come close to this value. The FUEL and EXAM employees lose significant time (about 100 minutes) to delays.

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[1] The distribution of the averages was assumed to be approximately Gaussian so that simultaneous Student t intervals could be applied. Common seeds were used for all modifications to induce a positive correlation between the modifications and to highlight the differences in the performances that were obtained. The possibility for correlation rendered the more specialized joint confidence procedures (e.g., Dunnett[3]) inapplicable, so the Bonferroni procedure[4] was applied.

[2] Dollar estimates exclude capital costs and assume $30/man-hour average loaded wages, 48 work-weeks/year, 5 days/week, and 276 employees.

[3] The facility average is computed by averaging the availability across all three employee categories.

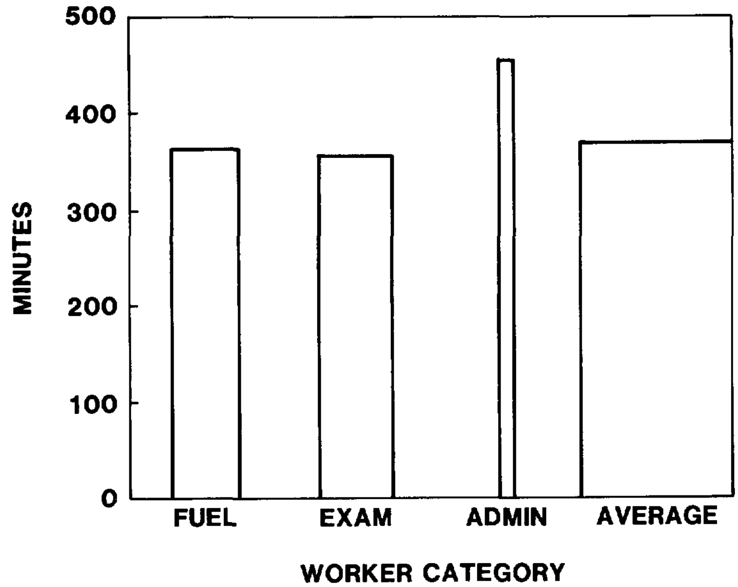

Figure 3. Base Case Worker Availability

Figure 4 displays the magnitudes of some potential sources of unavailability[1] for each category of employee. For example, EXAM Workers spend roughly 48 minutes in their changerooms during one day (8 passages at 6 minutes per passage). The FUEL Workers accumulate most of their unavailability in the clothing changerooms (about 64 minutes); about 25 minutes are spent in portal systems and 21 minutes in transit. Total transit time includes all time spent moving about in the facility during the day. Portal time includes PGS portal system time arriving and leaving the FMEF and Interior Guard Station portal system time. The EXAM Worker portal time is high because only one EXAM automated portal is used. Changeroom time is about 48 minutes.

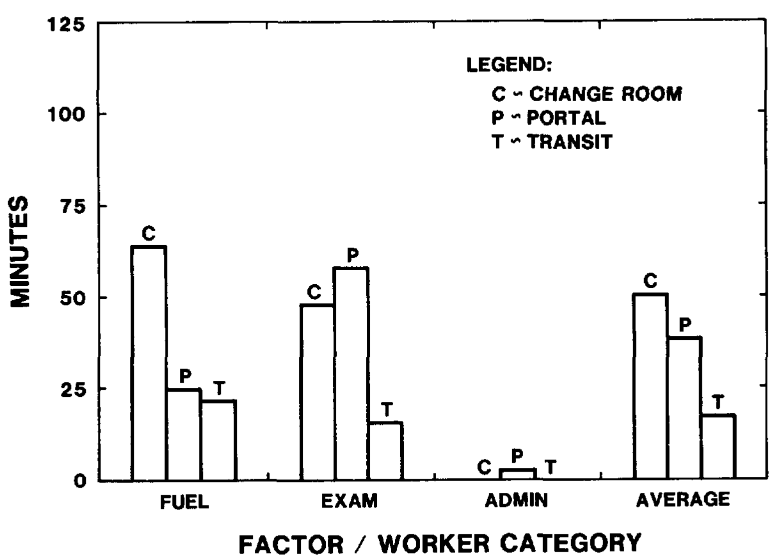

Figure 4. Base Case Unavailability Contributions

[1]Adding the unavailability contributions in Figure 4 to the availability times in Figure 3 sums to more than 460 minutes. This occurs because workers arrive early and will have passed through some of the portals and perhaps the changerooms before the shift starts. The same phenomenon occurs at quitting time when some workers leave their stations too late to get through all of the portals and changerooms before the shift ends. In both cases, these extra delay times do not occur during the 8½ hours of the shift and do not reduce availability.

Changeroom time is the largest source of unavailability for the "average" FMEF Worker. Total portal time is next, and transit time is the least significant of these three sources. The statistics for the portal systems are listed in Figure 5.

Queueing Statistic	Perimeter	FUEL Subsystem	EXAM Subsystem
Average Time: (Minutes)	1.7	2.6	6.8
Maximum Time: (Minutes)	6.7	12.0	26.9
Maximum Number: (People)	47	61	72

Figure 5. Portal Queueing Statistics

Four sets of modifications to the base case were studied:

- Portal Modifications: Vary number used and processing times,
- Lunch Break Modifications: Stagger lunch periods and vary the sites where workers spend lunch,
- Shift Scheduling Modifications: Vary starting schedules of different worker categories, and
- Transit System Modifications: Implement various express personnel elevator systems or eliminate the elevator altogether.

Note that shift scheduling modifications stagger the entire work shift for the affected worker, so these modifications include lunch break staggering. Staggering is defined here as scheduling of elements (such as arrival, break, and quitting time) differently for certain subgroups of FMEF Workers.

CONCLUSIONS BASED UPON ANALYSIS OF FMEF

Some general conclusions concerning FMEF operating configurations have been drawn from the results of the simulations. The following is a summary of results for the primary performance measure, availability[1]:

- Staggering arrivals between employee categories would have a minimal effect,
- Staggering lunch breaks between employee categories would have a minimal effect,
- An express elevator system could save approximately $70K/Year,
- Use of three interior portals each for the FUEL and EXAM Workers could save approximately $670K/Year, and
- Establishment of an interior break area for the FUEL Workers could save approximately $700K/Year.

If the queueing statistics corresponding to secondary performance measures are examined, the effects of staggering shift elements such as arrival, breaks, and lunch are substantial in terms of reducing congestion at various locations. The reduction of congestion that is brought about at certain locations by inter-category staggering does not, however, significantly improve availability. An effective means for both reducing congestion and increasing availability could result from staggering shift elements within--in contrast to between--worker categories, providing there is no productivity dependence among workers in the same category.

Total dollar savings due to increasing availability can amount to approximately $1,400,000/Year. Moreover, the queueing statistics are improved across the board.

SUMMARY

The use of the stochastic network approach to quantify the effects of changes in the design of personnel control systems on employee availability has been demonstrated. As illustrated by the example application, substantial savings in the operating costs at a nuclear facility are possible through relatively inexpensive design modifications.

The technique used in this study was Q-GERT, a network modeling vehicle and computer analysis tool. This technique is particularly well-suited for the modeling and analysis of personnel control systems within the framework of a stochastic network.

[1] Dollar estimates exclude capital costs and assume $30/man-hour average loaded wages, 48 work-weeks/year, 5 days/week, and 276 employees.

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ENERGY DISPERSIVE X-RAY FLUORESCENCE ANALYSIS OF URANIUM AND PLUTONIUM IN WET SCRAP PROCESS SOLUTIONS

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Abstract

Energy Dispersive X-Ray Fluorescence Analysis of Uranium and Plutonium in Wet Scrap Process Solutions

Uranium and plutonium solutions representative of those expected from the scrap recovery processes of fast breeder reactor fuel manufacturing operations have been analyzed "at-line" by the technique of x-ray fluorescence (XRF). Nitrate solutions containing from 0.1 to several hundred grams heavy metal per liter were measured, with emphasis on process control measurements of high concentration solutions. XRF system response to concentration, Pu/Pu+U, acid molarity, and to two plutonium isotopics is discussed.

Results have indicated that analytical precision of better than 1% is achievable for 10 minute analyses of solutions in the 100-450 gm/ℓ range. The detection limit was found to be 0.1 gm/ℓ, while at concentrations above 100 gm/ℓ, sample self attenuation is the most significant factor affecting analytical precision.

Introduction

In support of fast breeder reactor fuel fabrication activities, scrap mixed oxide powder and pellets will be processed to yield a mixed oxide powder available for recycle to the fuel manufacturing operation. Associated scrap recovery operations typically include: dissolution of mixed oxide scrap, recovery and purification of mixed nitrate solution via solvent extraction techniques, and co-conversion to powder.

To optimize control of the wet chemical processes of scrap recovery operations, it is necessary to monitor or measure the contents of certain tanks and process streams on a timely basis. For example, the contents of a feed tank continuously supplying solution would be rapidly analyzed. Based on comparison of the analysis results to process specifications, the batch would be scrapped, reworked, or accepted. In support of such process control measurement needs, a technique utilizing x-ray fluorescence (XRF) to determine actinide concentrations has been tested at the General Electric Vallecitos Nuclear Center (GE-VNC).

Experimental

For this work a 15 milliCurie Cobalt-57 source was used to excite the $K\alpha$ x-rays of uranium and plutonium in solution. XRF analysis was performed "at-line", with the Co-57 source and detector assembly interfaced to a glovebox containing the XRF standards. Figure 1 shows the Co-57 source and sampling geometry. For analysis a sample bottle is transferred to the fluorescence position via a trolley cart mechanism. The excitation source consists of six Co-57 pellets mounted in a lead annular holder. A portion of the uranium and plutonium characteristic x-rays generated travels from the sample through the annulus, and to the detector. The source holder is mounted on a wheel plate which can be rotated to remove the source and permit passive (unfluoresced) counting of a sample's radioactivity. The source assembly and detector are isolated from the glovebox interior by 0.38 mm of PVC "bag" material.

Co-57 has a 270 day half life, emitting gamma rays of 122 keV (87%), 136 keV (11%), and 692 keV (.14%). Impurities in the source, mainly trace amounts of Co-56 and Co-58, are very active (70 day half-lives), emitting high energy gammas of 847 and 810 Kev with branching intensities near 100%. Lead and tungsten are employed to shield the detector from these radiations as they could create a Compton continuum background which would severely degrade the x-ray peak-to-background ratios. Typical impurity content for new Co-57 sources is < 0.15 weight percent Co-56 + Co-58. For this work, the Co-57 source was made from "aged" Co-57 in which the highly active impurities were allowed to decay for over one year. Co-56 and Co-58 content was << .005% during XRF analysis. The use of aged Co-57 substantially reduces the detector shielding requirements, ultimately leading to smaller sample-to-detector distances and higher count rates.

The characteristic x-rays of interest were detected by a 7 mm deep by 200 mm^2 intrinsic germanium detector having a full width at half maximum resolution of 510 eV at 122 kev. The preamplifier was of the resistive feedback type. The preamplified detector signals were sent to am amplifier, with a pulse pileup-rejector/live-time-corrector connected in parallel. Non-compound pulses were analyzed by a Tracor Northern TN1710 LSI-11 based multichannel analyzer, interfaced to a dual drive floppy disk unit and a printer/plotter terminal.

Plutonium, natural uranium, and uranium/plutonium standard solutions typical of those expected from the wet chemical processes of interest were analyzed. All standards were uranyl and/or plutonium nitrate contained in sealed 60 ml polypropylene sample bottles. The standards ranged in concentration from 0.01 to 450 grams heavy metal per liter with Pu/(Pu+U) from 5% to 30%. The U/Pu solutions contained two different plutonium isotopics: one representative of plutonium from reprocessed high burnup fuel (nominally 78% fissile content), and another of lower burnup Pu (nominally 89% fissile). Pure plutonium solutions contained 92% fissile content Pu. Technical data for the standards is given in Table 1.

Results and Discussion

Figure 2 shows a typical XRF spectrum obtained for a 200 seconds live-time count of a U/Pu solution containing 30 gms/ℓ Pu and 70 gms /ℓ U. Note the dominant broad peak centered at channel 1670 (83.5 keV). This peak results from the primary exciting radiation of Co-57 (122 keV gamma) Compton scattering incoherently with low Z atoms of the solution. A smaller peak of similar nature at channel 1800 (90 keV) results from the less intense 136 kev Co-57 gamma. The intensity of these incoherent scatter peaks increases with decreasing heavy metal (U+Pu) concentration, while the energy of the peaks decreases slightly with decreasing concentration. The solution's mean attenuation coefficient and the mean scattering angle of the incident Co-57 radiation are responsible for this behavior.

The plutonium $K\alpha_1$, $K\alpha_2$ and uranium $K\alpha_1$, $K\alpha_2$ x-ray peaks appear in Figure 2 at channels 2073 (103.65 keV), 1990 (9945 keV), 1969 (98.45 keV) and 1893 (94.65 keV) respectively. X-rays of neptunium and several unresolved gamma rays are also prominent in this region. The neptunium and a portion of the uranium $K\alpha$ x-ray peaks result from the emission of characteristic x-rays during the alpha decay of plutonium and its daughters, not from Co-57 induced fluorescence. For solutions containing plutonium, the passive (unfluoresced) component of the XRF spectrum complicates quantitative x-ray intensity measurements. As a result, for XRF analysis the fluoresced and passive spectra must be subtracted to yield the net Co-57 excited x-ray spectrum. Figure 3 shows the net spectrum resulting from the subtraction of the passive component from the spectrum of Figure 2. Note that no gamma or neptunium peaks appear in the net spectrum and that the Pu $K\alpha_1$ and U $K\alpha_2$ peaks are completely resolved while the Pu $K\alpha_2$ and U $K\alpha_1$ peaks overlap slightly. Such net spectra were used for XRF analysis of all solutions containing plutonium. For pure uranium solutions, the passive component is insignificant and thus analysis of the fluoresced spectrum alone is sufficient. Both fluoresced and passive spectra were acquired at the following livetimes: 2000 seconds at 0.1 gm/ℓ, 500 seconds at 1 gm/ℓ, and 200 seconds for 10 gm/ℓ and higher. The maximum deadtime of the electronics was 45% for the fluoresced spectrum of the 100 gm/ℓ Pu solution.

Am-241, a plutonium daughter resulting from the beta decay of Pu-241, emits an intense 59.5 keV gamma (not shown in Figure 2) that is largely responsible for the 35% deadtime associated with the acquisition of the Figure 2 spectrum. For the solution of Figure 2, the Am-241 gamma peak contains 2.7 million counts, approximately 60% of the total spectrum counts. Am-241 content will be lowest for recently reprocessed solutions and will increase with the decay of Pu-241. To decrease count rates enough so that the detector electronics would not become saturated, a graded filter of 0.79 mm thick cadmium and 0.44 mm copper was placed in front of the detector. The filter was in place for all XRF spectra obtained.

The uranium and plutonium $K\alpha$ x-ray intensities of the net Co-57 excited (fluoresced minus passive) XRF spectra were determined as follows. A computer program was written to locate and integrate the x-ray peaks of interest. The background continuum beneath a peak was estimated by the method of Gunnink.(1) For U/Pu solutions the U $K\alpha_1$ and Pu $K\alpha_2$ peaks were unfolded by inferring the Pu $K\alpha_2$ counts from the Pu $K\alpha_2$ counts of pure plutonium solutions. The Pu $K\alpha_1$ peak was used to calibrate for concentration for pure plutonium solutions. For U/Pu solutions, the U $K\alpha_2$ + Pu $K\alpha_1$ (rather than U $K\alpha_1$ + Pu $K\alpha_1$) net peak intensities were used to calibrate for heavy metal concentration, since the U $K\alpha_1$ precision resulting from unfolding the U $K\alpha_1$ and Pu $K\alpha_2$ peaks was comparable to that of the U $K\alpha_2$ peak. U/Pu ratios were determined from U $K\alpha_2$/Pu $K\alpha_1$ measurements. For all measurements the $K\alpha$ peak intensities were divided by the gross counts in channels 1600 to 1741 of the incoherent scatter peak. The synergistic use eliminates the need to account for source decay, mitigates the decreased sensitivity caused by sample self attenuation at high concentrations, and compensates for minor variations in sampling geometry. (2)

XRF system response over a large range of heavy metal concentrations (0.1 to 300 gm/ℓ) is shown in Figure 4. Kα/GI values for uranium, plutonium, and U/Pu solutions are plotted (Kα/GI = net Pu $K\alpha_1$, U $K\alpha_2$, or (Pu $K\alpha_1$ + U $K\alpha_2$), divided by Gross incoherent scatter counts).

The data of Figure 4 are mean values for four calibration runs in which each run was performed with the sample bottles in a different rotational orientation (i.e., 0°, 90°, 180°, 270°). For the Pu data net Pu $K\alpha_1$ count rates ranged from 1.4 cps at 0.1 gm/ℓ to 1170 cps at 100 gm/ℓ. For the U/Pu solutions, U $K\alpha_2$ + Pu $K\alpha_1$ count rates were 10 cps at 1 gm/ℓ and 1380 cps at 300 gm/ℓ. For the uranium solutions, U $K\alpha_1$ count rates were 1.3 cps and 1560 cps at 0.1 and 300 gm/ℓ respectively, with U $K\alpha_2$ count rates of 7.6 cps and 930 cps at 1 and 300 gm/ℓ. The practical concentration detection limit for the present system is represented by 0.1 gm/ℓ, since active spectra of 0.01 gm/ℓ Pu and U solutions acquired for over 5 hours indicated no presence of Kα peaks.

The overall precision of the Kα/GI measurements of Figure 4 is in considerable excess of the total error resulting from Poisson (counting) statistics, background subtraction, and passive spectrum subtraction. The discrepancy has been correlated with sample bottle variability. Overall Kα/GI precision was as high as 4% over the 1 to 450 gm/ℓ range. In contrast, the errors in Kα/GI resulting from only counting statistics, background subtraction, and passive spectrum subtraction combined were only 8%, 2%, 0.7%, 0.4%, 0.3% and 0.2% at 0.1, 1, 10, 50, 100 and 300 gm/ℓ respectively. These latter values represent the precision achievable for an "in-line" sampling station in which the sample cell is integral with the process piping.

To estimate analytical precision (in grams/ℓ) the slope of the Kα/GI vs. concentration curve, in addition to the precision of Kα/GI, must be considered. Figure 5 shows uranium $K\alpha_1$ and $K\alpha_1$/GI calibration curves for high concentrations where loss of measurement sensitivity due to sample self attenuation is most critical. (The data of Figure 5 should not be compared directly to Figure 4, since the Figure 5 solutions were 0.5 M HNO_3 and of greater volume). With the precision of the Kα/GI measurement given by σ_m, the analytical precision (in grams/ℓ) can be estimated by:

$$\sigma_a = \sigma_m/S$$

where S is the slope (ℓ/gm) of the Kα/GI calibration curve at the measured value of Kα/GI. With S given by the first derivative of the data fit and σ_m including Poisson statistics and background subtraction errors only the analytical precision of uranium concentration measurements was as follows: 0.3% at 100 gm/ℓ; 0.4% at 165 gm/ℓ, 235 gm/ℓ, and 300 gm/ℓ; 0.5% at 350 gm/ℓ, 400 gm/ℓ; and 0.6% at 450 gm/ℓ. These values represent the best analytical precision achievable with the sampling geometry employed, since the errors associated with sample bottle irregularities have been excluded. The analytical precision of heavy metal concentration measurements for U/Pu solutions containing 30% Pu should not be appreciably different since self attenuation will be comparable.

The decrease in GI intensity with increasing concentration was seen to degrade Kα/GI measurement precision such that in the 100-450 gm/ℓ range, $K\alpha_1$ precision was better than that of $K\alpha_1$/GI by nearly a factor of two. Notwithstanding, the analytical precision obtained using $K\alpha_1$/GI was slightly better than that corresponding to $K\alpha_1$ alone since self attenuation has a much greater effect on $K\alpha_1$ than on $K\alpha_1$/GI. However, the analytical precision associated with $K\alpha_1$ was still better than 1% for 100-450 gm/ℓ.

XRF Measurements over a 5% Pu to 30% Pu range at constant heavy metal concentration (10 gm/ℓ) indicated no evidence of interelement effects resulting from the fluorescence of uranium by plutonium Kα x-rays. The data are shown in Figure 6, overall measurement precision being better than 5%. On an atom basis the 78% fissile Pu contains only 0.08% less plutonium than the 89% fissile Pu, negligible for process control measurements. With increasing heavy metal concentration (for constant % Pu), the sample matrix will self attenuate the lower energy U Kα x-rays proportionally more than the Pu Kα x-rays. Attributable to this effect, Pu $K\alpha_1$/U $K\alpha_2$ values were found to increase by 10% over the 10 to 300 gm/ℓ range.

The 235 gm/ℓ uranium standards at 0.5M, 3M, and 6M were used to assess acid molarity effects. If the heavy metal concentration remains constant and the HNO_3 molarity increases, Compton scattering into the incoherent scatter peak will increase. Self attenuation of the Kα x-rays will increase. Therefore, the Kα/GI ratios can be expected to decrease with increasing HNO_3 molarity. At 235 gm/ℓ, from .5M to 6M HNO_3, a one unit change in molarity was found to affect Kα/GI by approximately one percent, consistent with previous measurements performed at 100 gm/ℓ and in 2 to 8 M HNO_3.[3]

To simulate an in-line process control measurement, the sample bottle was held in the normal position but enclosed in a type 304 stainless steel sleeve having a 38 mm inside diameter and a .64 mm thick wall. In addition, a 6.4 mm thick polycarbonate sheet simulated a measurement window in a glove box wall. The stainless steel tube alone was found to decease Kα count rates by approximately 25% and to degrade peak-to-background by 30%. While the attenuation of U and Pu Kα x-rays by the polycarbonate material was small, the intensity of the incoherent scatter peak was increased considerably (by 200% at 300 gms heavy metal per liter) to a value (∿2000 cps) which remained essentially independent of concentration from 10-300 gm/ℓ . Also, the positioning of the window decreased the mean scattering angle of the excitation radiation, shifting the incoherent scatter peak upward in energy by approximately 0.5 keV. As a result, the stainless steel and window combined degraded peak-to-background by nearly 50%. However, XRF spectra of 30% Pu solutions from 50-300 gm/ℓ acquired in the simulated in-line mode were considered to be of a quality suitable for process control measurements, since analyses of ten minutes duration (including the acquisition of passive and active spectra) yielded x-ray peak analysis errors (including Poisson statistics, passive and background subtraction errors) of less than 1%.

Acknowledgement

This work was sponsored by the U.S. Department of Energy.

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3. Camp, D. C., et al, "Non Destructive Energy-Dispersive X-Ray Fluorescence Analysis of Product Stream Concentrations for Reprocessed LWR Fuels", UCRL-52616, January 1979.

TABLE 1
XRF Standards

U+Pu gms/ℓ	M, HNO_3	$\frac{Pu}{Pu+U}$	% Fissile Pu
.1,1,10,50 101,295	6	0	-
100,165,235,300, 350,400,450	0.5	0	-
235	0.5, 3, 6	0	-
.1, 1, 10, 50,100	6	1	92%
.1, 1, 10, 50, 100,301	6	.30	89%
10	6	.05, .15, .25	89%
10	6	.10, .20, .30	78%

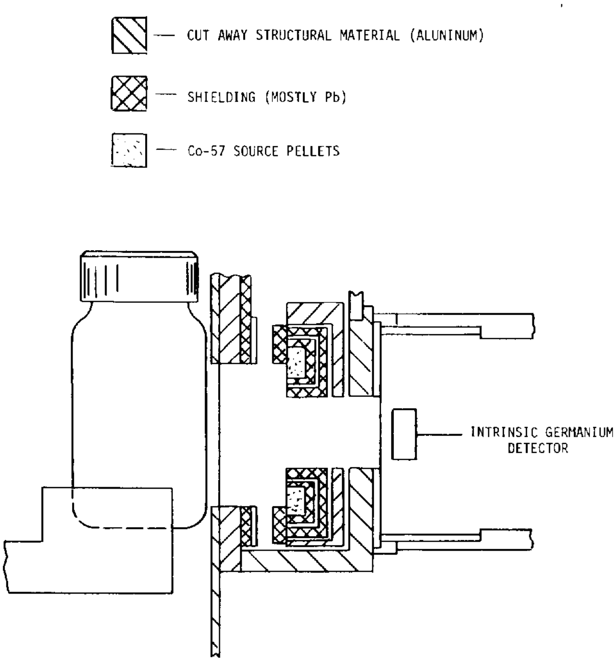

FIGURE 1 XRF Source Holder Assembly

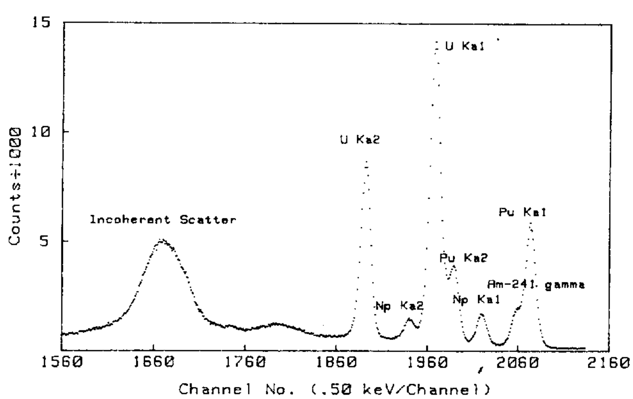

FIGURE 2 XRF Spectrum Obtained for a 200 Seconds Livetime Count of a Solution Containing 30 gms/ℓ Pu and 70 gms/ℓ U ($K\alpha 1 = K_{\alpha_1}$, $K\alpha 2 = K_{\alpha_2}$)

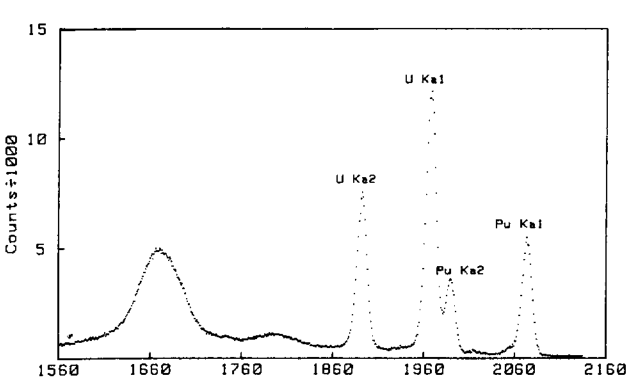

FIGURE 3 Net XRF Spectrum Resulting from Subtracting the Passive Component from the Spectrum of Figure 2 ($K\alpha 1 = K_{\alpha_1}$, $K\alpha 2 = K_{\alpha_2}$)

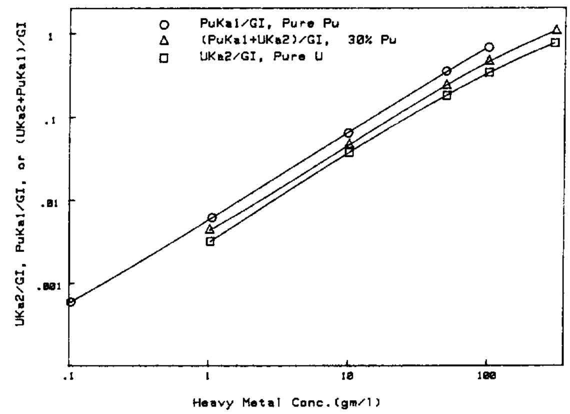

FIGURE 4 XRF Response to Concentration ($K\alpha 1 = K_{\alpha_1}$, $K\alpha 2 = K_{\alpha_2}$)

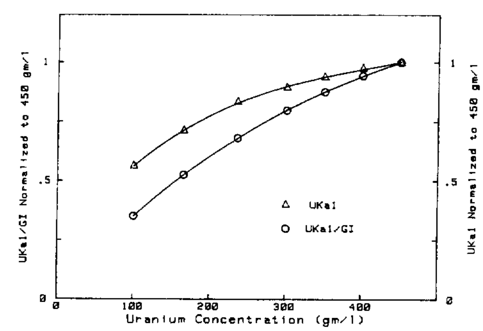

FIGURE 5 Uranium $K\alpha_1$ and $K\alpha_1$/GI Calibration Curves at High Concentrations where Self Attenuation is Critical ($K\alpha 1 = K_{\alpha_1}$, $K\alpha 2 = K_{\alpha_2}$)

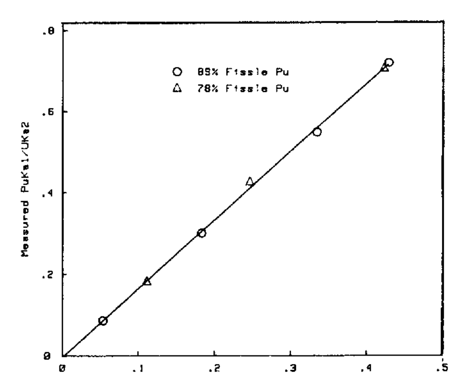

FIGURE 6 XRF Response to Pu/U at 10 gm/ℓ ($K\alpha 1 = K_{\alpha_1}$, $K\alpha 2 = K_{\alpha_2}$)

NUCLEAR MATERIAL SAFEGUARDS SURVEILLANCE AND ACCOUNTANCY BY ISOTOPE CORRELATION TECHNIQUES*

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Abstract

The purpose of this study is to investigate the applicability of isotope correlation techniques (ICT) to the Liquid Metal Fast Breeder Reactor (LMFBR) fuel cycles for nuclear material accountancy and safeguards surveillance. The ICT allows a level of verification of the fabricator's fuel content specifications, the irradiation history, the fuel and blanket assemblies management and scheduling within the reactor, and the subsequent spent fuel assembly flows to the reprocessing plant. The investigation indicates that there exist relationships between isotopic concentrations which have predictable, functional behavior over a range of burnup. Several cross-correlations serve to establish the initial core assembly-averaged compositions. The selection of the more effective functional relationships will depend not only on the level of reliability of ICT for verification, but also on the capability, accuracy and difficulty of developing measurement methods. The propagation of measurement errors on the correlation functions and respective sensitivities to isotopic compositional changes have been examined and found to be consistent with current measurement methods.

Introduction

The feasibility of utilizing fission product and heavy element isotopic ratios has been explored by many investigators[1-6] for verifying burnup of fissile material input to a reprocessing plant for the LWR fuel assemblies. The heavy element isotopic correlations may be employed for the independent verification and evaluation of the Pu/U ratio measurement by the use of wet chemistry and isotope dilution mass spectroscopy, and to establish that the integrity of the fuel content has been maintained from the output of the fuel fabricator plant and the input to the reprocessing plant.

The changes in the isotopic composition of a fuel assembly with burnup are a measure of the irradiation history of the fuel in a power reactor. Initial experimental data on LWR reprocessed fuel indicates that there may exist relationships between isotopic concentrations which have a predictable, functional behavior over a range of reactor operating conditions and burnup. However, the range of burnups in the reprocessing data are found to be limited at very low burnups (<10,000 MWD/T) and very high burnups (>25,000 MWD/T). The validity of extrapolating the correlation functions much beyond the range of the burnup data bank is uncertain and should be established by computation and confirmed with precisely tailored experiments. In part, preliminary efforts in this direction have been initiated in Europe[7,8,9,10]. This paper presents the initial phase of a U.S. study program and involves the computation of isotopic correlations for an LMFBR fuel cycle.[11,12] The LWR fuel cycle phase of the study is currently in progress.

The selection of the more safeguards effective functions will depend not only on the level of reliability of ICT for verification, but also on the capability and difficulty of developing measurement methods. The sensitivity of ICT analysis to measurement accuracies was analyzed in order to identify limitations of the technique within the present measurement capabilities, and to identify measurement improvements that would increase the sensitivity of this technique.

The Basis For Isotope Correlations

Some of the more simple relationships involving combinations of isotopic concentrations that exhibit a reasonably monotonic behavior over a broad range of reactor conditions and burnup are: Pu/U vs. depletion ^{235}U, Pu/U vs. (100 - ^{239}Pu), Pu/U vs. $^{239}Pu \times {}^{242}Pu/{}^{240}Pu^2$, and ^{236}U vs. ^{235}U. Of the many preliminary functions that have been suggested, the most effective functions are those having a linear or almost linear behavior. These linear relationships being independent of reactor oper-

*Work performed under the auspices of the U.S. Department of Energy.

ating conditions and burnup, effect a means of verifying the input to a reprocessing plant, and methods for establishing internal consistency of input analytical measurements, and a level of verification on initial isotopic concentrations prior to burnup.

Reactor System

A representative LMFBR was studied to gain an insight in applying ICT to fast breeder reactor technology as part of the International requirements in developing a safeguards system for the currently and near-term operating fast breeder reactors.[13] For computational purposes the core is divided in azimuthally symmetric 1/6 segments and radially zoned into five concentric regions or columns surrounding a central column, as shown in Fig. 1. The central column, is a control rod;

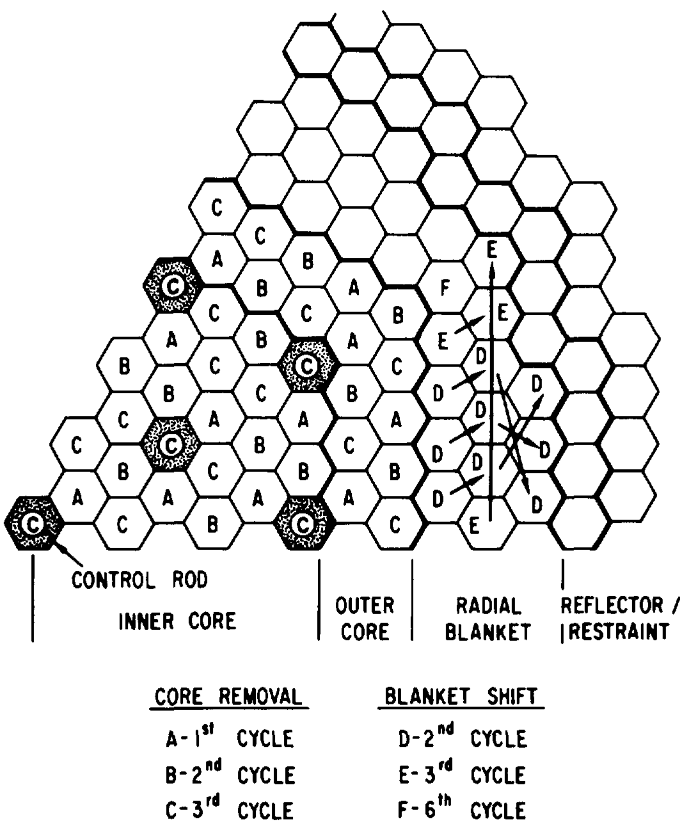


Fig. 1. Core and Radial Blanket Refueling Scheme

columns two, three, and four comprise the inner core assemblies; column five, the outer core assemblies; and column six, the radial blanket. The initial compositions of the assemblies in the two respective core regions, inner (low enrichment) and outer (high enrichment), and the blanket regions are contained in Table I. The core compositions are based on the LMFBR integral-assembly design of fuel elements and depleted-uranium axial blanket sections.

As a preliminary to the discussion of the graphs and subsequent analyses, certain aspects of the curve plotting should be noted. Referring to

TABLE I. Initial Composition by Column

	Column 2, 3, 4	Column 5	Column 6
Pu/U (g/te)	1.32×10^5	2.04×10^5	0.0
^{235}U (w/o)	0.447	0.432	0.217
^{236}U (w/o)	0.0	0.0	0.0
^{238}U (w/o)	99.6	99.6	99.8
^{238}Pu (w/o)	1.00	1.00	0.0
^{239}Pu (w/o)	67.3	67.3	0.0
^{240}Pu (w/o)	19.2	19.2	0.0
^{241}Pu (w/o)	10.1	10.1	0.0
^{242}Pu (w/o)	2.40	2.4	0.0

the isotopic correlation functions presented in Figs. 2a and 2b, the points on the graphs are the program output of the functions and are numbered with increasing burnup. In the lower right hand corner of the graph, an arrow is included to indicate the general direction of burnup. Also noted are the reactor region identification and the curve numbers that correspond to the specific correlation functions listed in Table II. In the set of functions for simulat-

TABLE II. Isotopic Correlation Functions

1. Pu/U vs. D-235
2. Pu/U vs. 100-^{239}Pu
3. ^{236}U vs. ^{235}U
4. ^{239}Pu xx 2 vs. ^{235}U
5. ^{240}Pu vs. ^{239}Pu(100-^{239}Pu
6. $^{239}Pu \times ^{240}Pu$ vs. $^{235}U \times ^{241}Pu$
7. $^{240}Pu \times ^{241}Pu$ vs. $^{235}U \times ^{242}Pu$
8. ^{240}Pu vs. D(^{235}U xx 2)
9. ^{239}Pu xx 2(100-^{239}Pu)/^{235}U xx 2 vs. 100-^{239}Pu
10. (^{239}Pu xx 2) (^{240}Pu xx 2) vs. ^{240}Pu
11. ^{239}Pu(100-^{239}Pu) vs. D($^{235}U \times$ (^{239}Pu xx 2))
12. Pu/U vs. $^{239}Pu \times ^{242}Pu/(^{240}Pu$ xx 2)
13. Pu/U vs. $^{241}Pu/^{240}Pu$
14. Pu/U vs. $(^{241}Pu + ^{242}Pu)/^{240}Pu$

ing substitutions, the graphs list the normal and the changed end-values of the ordinate and abscissa, and the percentage difference between the two for each of the axis variables.

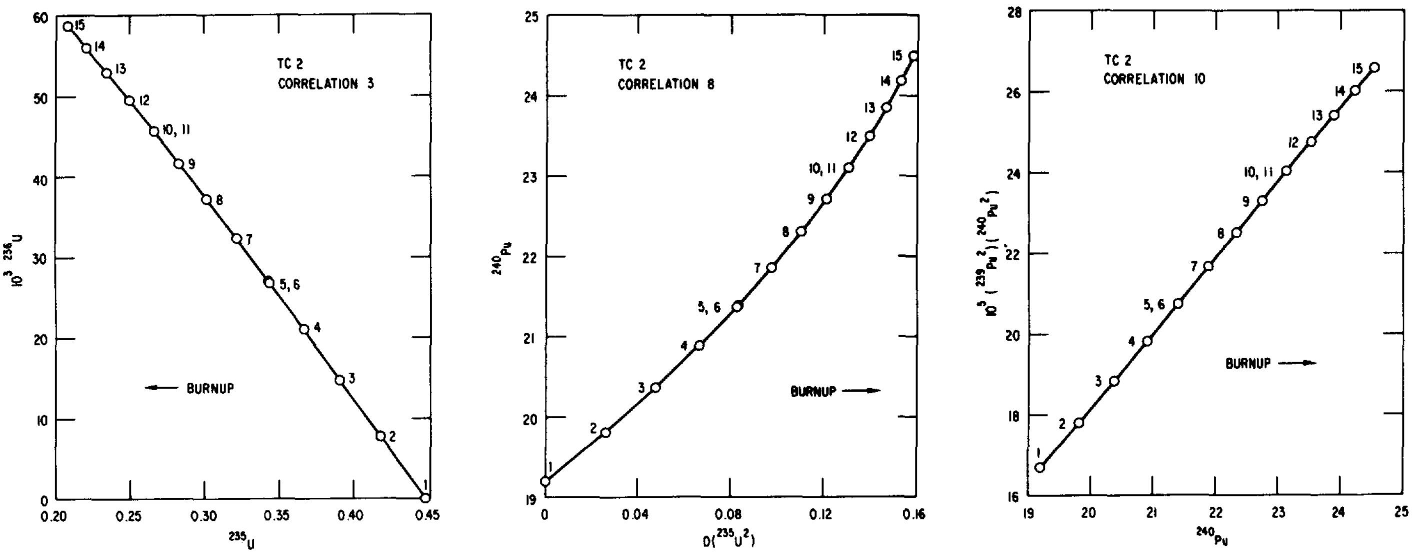


Fig. 2a. Isotope Correlation Functions

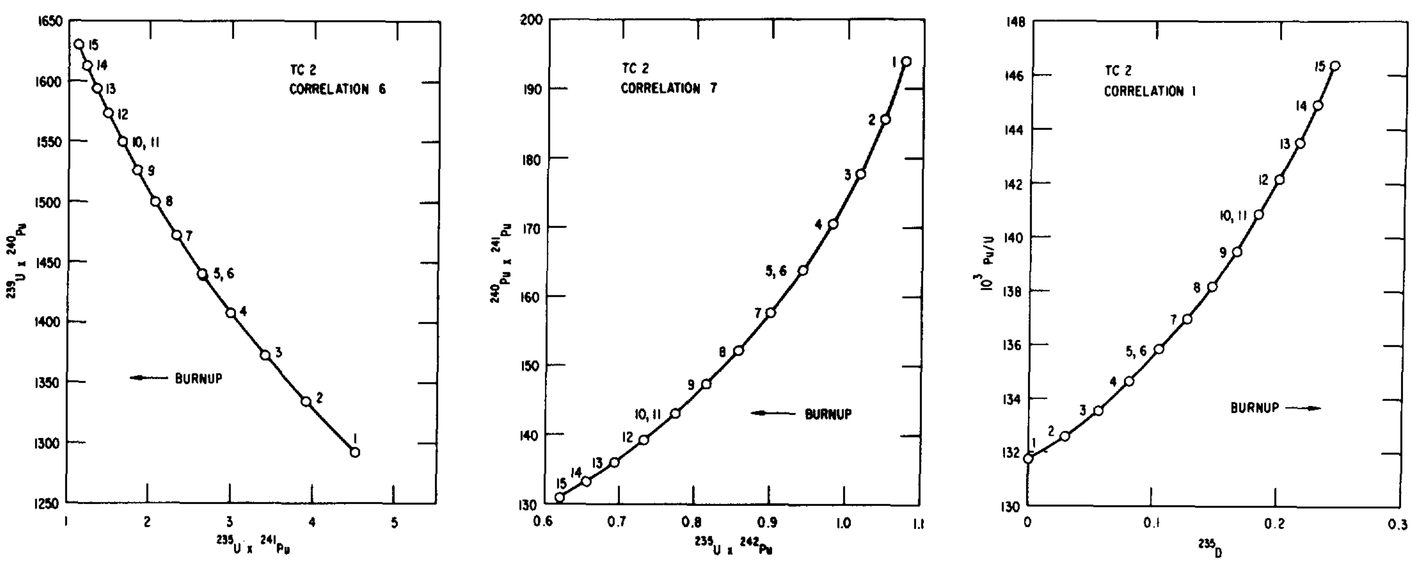


Fig. 2b. Isotope Correlation Functions

The units for all of the graphs are weight percent of the isotope compared to the total weight of that element except for Pu/U which is in grams of plutonium per metric ton of uranium. ^{235}D represents the depletion of ^{235}U or the difference between the concentration at a given burnup and the initial unirradiated concentration. Similarly, $D(^{235}U^2)$ and $D(^{235}U \times {}^{239}Pu^2)$ are the difference between a given burnup and the beginning of the cycle.

The correlation functions exhibiting linear behavior, or monotonically well-behaved curvature, appear to be most effective for determining initial isotopic compositions by extrapolating to zero burnup. The position of the measured correlation point when coupled with the expected behavior of the correlation function (the shape of the curve) for a specific assembly position, may be utilized as a measure of safeguards to detect inconsistencies in nuclear material management within some level of assurance. The margin of error is influenced by the measurement accuracy and the propagation of these measurement errors for the specific correlation function.

There are several cross-correlations that may serve, in a verification mode, to establish the initial core assembly-averaged composition. Referring to the TC-2 curves, the functional relationship curve-3 (^{236}U vs. ^{235}U) indicates that for the core assemblies the correlation behaves in a linear manner. If this can be substantiated experimentally, then the slope may be determined and used to extrapolate to the pre-irradiation condition from the measured point. This initial determination of ^{235}U concentration may be used in providing or identifying a known quantity in the other functionals.

Referring to TC-2, curve-8, ^{240}Pu vs. $D(^{235}U^2)$ is again found to be a well-behaved function and may be used to verify curve-3 and consequently may provide the initial ^{240}Pu concentration. This would utilize the value for ^{235}U from curve-3 since the initial ^{235}U enrichment is necessary to calculate the difference. With the initial ^{240}Pu determined in this manner, curve-10 $^{239}Pu^2 \times {}^{240}Pu^2$ vs. ^{240}Pu may then be used to verify the initial ^{239}Pu concentration. These three values may now be applied to curve-6 ($^{239}Pu \times {}^{240}Pu$ vs. $^{235}U \times {}^{241}Pu$), and curve-7 ($^{240}Pu \times {}^{241}Pu$ vs. $^{235}U \times {}^{242}Pu$), to obtain verification of ^{241}Pu and ^{242}Pu concentrations. The significance of this procedure is that this cross-correlation adds a constraint of consistency which in turn may be used in a matrix-profile manner to identify anomalies or unexpected variations in the isotopic compositions of the assemblies. The existence of the many monotonically well-behaved functions offers the possibility of identifying several patterns of cross-correlations.

Referring to TC-2, curve 1, Pu/U vs. ^{235}D, can provide the original plutonium concentration (enrichment) which distinguishes the inner and outer core assemblies. This again would use the value for ^{235}U from curve-3 since the initial ^{235}U enrichment is necessary to calculate the depletion. Several other correlations are also found to be well-behaved functionals and may be used in cross-correlating the plutonium isotopes.

From the comparison of the set of functions for TC-2 and the higher Pu concentration of the outer core region assemblies, the significant differences between corresponding correlations suggest that intermixing of the two differently enriched assemblies should be avoided. The change in the Pu/U ratio as a function of burnup is plutonium enrichment (concentration) dependent. The Pu/U ratio increases by about 11% in the inner (low enrichment) core assemblies and decreases by about 8% in the outer (high enrichment) core assemblies for the burnup range considered in this study. This implies that it would simplify ICT analysis if the fuel assemblies were dissolved in an ordered batch. However, it may develop that a preplanned intermixing of different rows of assemblies in a reprocessing program would also yield well-behaved functions which could be programmed for cross-correlations.

The isotopic correlations for the radial blanket assemblies are found to be linear functions or extremely well-behaved functions over the 6-year burnup period. There may exist a commercial incentive to process the radial blanket assemblies separately from the core assemblies. With the adoption of this reprocessing program, the potential exists to enhance independent verification of nuclear material flow between the fabrication plant output and the reactor operational phase of the fuel cycle.

Predissolver Stage

Isotope correlations including the trans-plutonium isotopes (neutron emitting 242-, 244-curium) and neutron assay methods have been investigated for implementation in determining plutonium concentration and burnup in fresh and spent LMFBR and in spent LWR fuel assemblies.[14,15] Preliminary studies[16] on neutron yield rates indicates that as a consequence of the high plutonium concentration level throughout the fuel irradiation period in an LMFBR, the spontaneous fission neutron yield from the 242-curium and 244-curium does not dominate the spontaneous fission neutron yield from the plutonium isotopes in the spent fuel stage (as is the case for an LWR spent fuel assembly). This suggests that the NDA assays of fresh and spent LMFBR assemblies may be more useful for plutonium accountancy than has previously been expected.

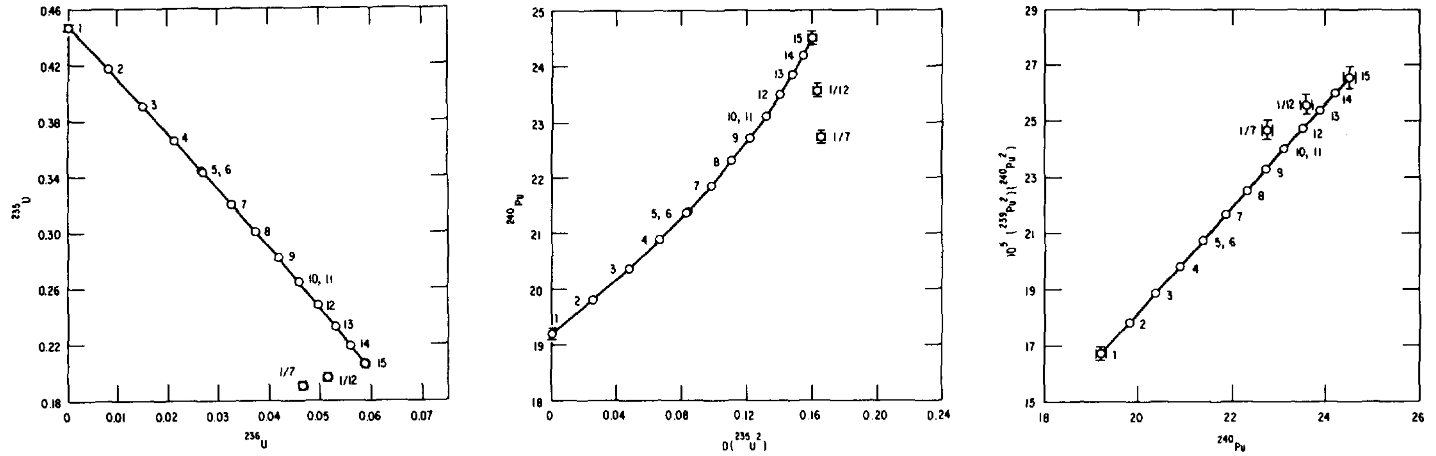
The preliminary results of isotopic content experiments from the reprocessed fast breeder fuels of the UKAEA Dounraey Prototype Fast Breeder reactor (PFR),[17] corroborate the computed estimates, and appear to give a consistent correlation between the isotopics and neutron emissions, including the time decay of neutron yields due to the time decay of the 242-curium isotope.

Although the relative concentrations of the plutonium isotopes, may vary over extended periods of burnup and decay cooling times, the spontaneous fission neutron yield from the plutonium is found to be almost constant. The determination of the curium isotope concentrations is made by a difference measurement of spontaneous fission source strengths between the fresh and spent fuel for a given assembly.

Sensitivity of ICT to Anomalies in Nuclear Material Flow

In order to illustrate the sensitivity of the isotope correlation techniques, the effect of a substitution or dilution equivalent of one radial blanket assembly for a core assembly (TC-2) in a seven assembly dissolver batch was simulated (15% dilution). The dilution may represent the partial interchange of fuel pins in the assemblies. All assemblies were assumed to have completed their final burnup stage. Representative changes in the correlation functions end-points are presented in Figs. 3a and 3b. Most of the correlation functions were found to be very sensitive to this type of substitution.

The above scheme of dilution equivalence was extended to include the case of one radial blanket assembly substitution in a twelve core assembly reprocessing batch (8% dilution). The results, included in Figs. 3 a,b and Fig. 4, indicate that the TC-2 end-value differences (outliers) are approximately half those of the previous case. There appear to be many correlations with large enough differences to detect substitution or dilution, with six of the correlation functions having changes between 7 and 15% and two of the correlation functions having changes greater than 15%.

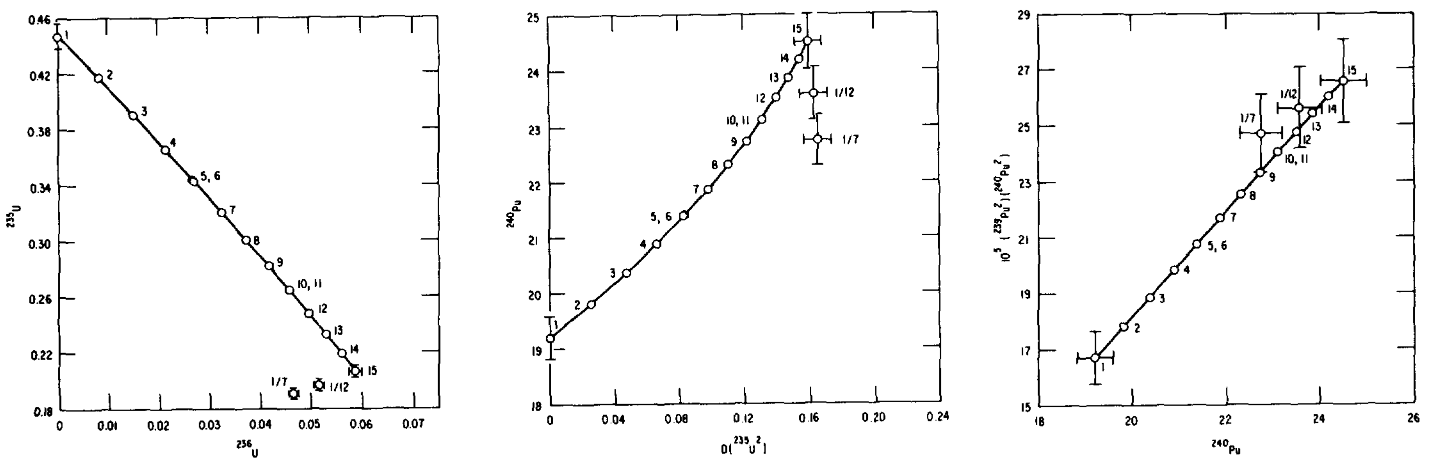


	NO SUBST.	1/7 SUBST.	% DIFF.	1/12 SUBST.	% DIFF.	TC-2
X	5.876×10^{-2}	4.657×10^{-2}	-2.076×10^{1}	5.159×10^{-2}	-1.220×10^{1}	3
Y	2.061×10^{-1}	1.903×10^{-1}	-7.662×10^{0}	1.969×10^{-1}	-4.503×10^{0}	0.5 %

	NO SUBST.	1/7 SUBST.	% DIFF.	1/12 SUBST.	% DIFF.	TC-2
X	1.574×10^{-1}	1.637×10^{-1}	3.978×10^{0}	1.612×10^{-1}	2.376×10^{0}	8
Y	2.449×10^{1}	2.273×10^{1}	-7.203×10^{0}	2.357×10^{1}	-3.787×10^{0}	0.5 %

	NO SUBST.	1/7 SUBST.	% DIFF.	1/12 SUBST.	% DIFF.	TC-2
X	2.449×10^{1}	2.273×10^{1}	-7.203×10^{0}	2.357×10^{1}	-3.787×10^{0}	10
Y	2.658×10^{6}	2.471×10^{6}	-7.054×10^{0}	2.562×10^{6}	-3.604×10^{0}	0.5 %

Fig. 3a. Measurement Errors (0.5%) Propagation on Isotope Correlation Functions



	NO SUBST.	1/7 SUBST.	% DIFF.	1/12 SUBST.	% DIFF.	TC-2
X	5.876×10^{-2}	4.657×10^{-2}	-2.076×10^{1}	5.159×10^{-2}	-1.220×10^{1}	3
Y	2.061×10^{-1}	1.903×10^{-1}	-7.662×10^{0}	1.969×10^{-1}	-4.503×10^{0}	2.0 %

	NO SUBST.	1/7 SUBST.	% DIFF.	1/12 SUBST.	% DIFF.	TC-2
X	1.574×10^{-1}	1.637×10^{-1}	3.978×10^{0}	1.612×10^{-1}	2.376×10^{0}	8
Y	2.449×10^{1}	2.273×10^{1}	-7.203×10^{0}	2.357×10^{1}	-3.787×10^{0}	2.0 %

	NO SUBST.	1/7 SUBST.	% DIFF.	1/12 SUBST.	% DIFF.	TC-2
X	2.449×10^{1}	2.273×10^{1}	-7.203×10^{0}	2.357×10^{1}	-3.787×10^{0}	10
Y	2.658×10^{6}	2.471×10^{6}	-7.054×10^{0}	2.562×10^{6}	-3.604×10^{0}	2.0 %

Fig. 3b. Measurement Errors (2.0%) Propagation on Isotope Correlation Functions

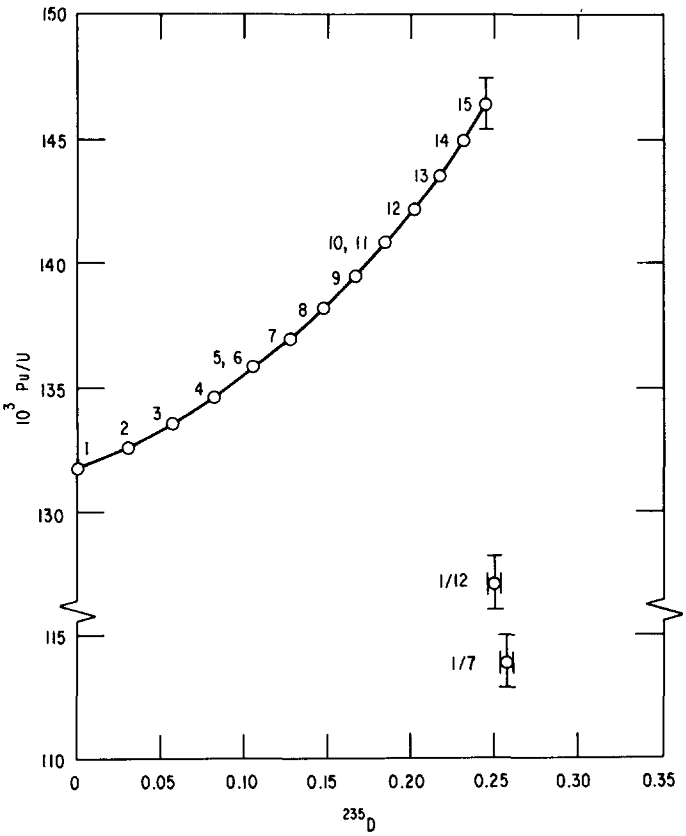
Sensitivity of ICT to Measurement Errors

The sensitivity of the correlation functions to the propagation of isotopic measurement errors was investigated. The study included errors at the 0.5, 1.0, 2.0 and 4.0% levels and were assumed to apply uniformly to each of the isotopes. This was adopted only for the scoping study and the next level of study will reflect the measurement accuracies for each isotope as experienced in current experiments.

The preliminary results of the effect of measurement errors are also included in Figs. 3 a,b for only the 0.5 and 2% measurement errors. The upper set of relations are based on the 0.5% error level and the lower set of functions are based on the 2.0% error level. The resolutions appear to be most adequate to discern one-seventh and one-twelfth substitutions in some of the functions. The result serves two purposes: 1) It identifies the more insensitive functionals to measurement accuracies and as such would aid in optimizing the set of functionals for cross-correlations, and 2) It establishes measurement methods design criteria which should be used as a guide in the development and selection of measuring instruments.

The sensitivities of some correlation functions to the mixing of inner and outer core assemblies or blanket and core assemblies are maintained for fabricator's isotopic specification accuracies within this range of measurement errors. However, much tighter fabricator's specifications are to be expected.

The Pu/U range of measurement error limits



	NO SUBST.	1/7 SUBST.	% DIFF.	1/12 SUBST.	% DIFF.	TC-2
X	2.410×10^{-1}	2.568×10^{-1}	6.554×10^{0}	2.503×10^{-1}	3.852×10^{0}	1
Y	1.464×10^{5}	1.137×10^{5}	-2.234×10^{1}	1.271×10^{5}	-1.313×10^{1}	0.5 %

Fig. 4. Isotopic Correlation Function, Pu/U vs. ^{235}D

expected in the assay of dissolver solutions, would readily allow discerning a substitution or dilution equivalent of a blanket assembly in a twelve core assembly batch. As shown in Fig. 4, the substitution results in a 13% decrease in the Pu/U ratio and 3.5% change in the ^{235}U depletion by the ICT method. The substitution of an inner-core assembly in a batch of twelve outer-core assemblies can also be detected within the error limits. Consequently the ICT method can be used as an effective safeguards measure and as an independent verification of those measurement requirements needing more demanding accuracy limits such as in estimating the plutonium input to the reprocessing plant.

Implementation

The isotopic correlation technique shows considerable promise for use in verifying the initial isotopic composition and isotopic depletion of discharged assemblies based on the measured ratios of several key isotopes, obtained at the dissolver stage in reprocessing. This establishes the integrity of the batch as planned for reprocessing. The verification of the quantitative estimate of the plutonium input into the reprocessing plant obtained by the Pu/U or Pu/U+Pu ratio method (Gravimetric Method) is not sufficient to detect certain anomalies in the nuclear material flow. The Gravimetric Method must be supplemented by the ICT to establish the relevance and consistency between the Pu/U ratio and burnup. Determining the inital and depleted isotopic concentration of the heavy metals and verifying the consistency of the isotopics by cross-correlations using the ICT is a necessary condition to identify anamolies in the flow of nuclear materials from the fabrication plant to the reprocessing plant.

Summary

The preliminary results from this study indicate that many of the correlation functions displayed linear or reasonably predictable behavior over the expected burnup period for LMFBR fuels. The ICT may be used in verifying reactor input fuel compositions and by cross-correlation methods can establish the relative compositions of the isotopics which are the unique signatures of burnup. This effects a safeguards relevancy to the Gravimetric Method in estimating the plutonium input into the reprocessing plant. The functional relationships were found to be sensitive to certain deviations from preplanned fuel management programs. The ICT is found to be sensitive to anomalies in nuclear material flow resulting from inner-core, outer-core and blanket substitutions or dilution equivalence. The propagation of measurement errors on the correlation function and respective sensitivities to isotopic compositional changes have been examined and found to be consistent with current measurement methods. Neutron assay methods based on neutron emissions due to plutonium have been investigated and were found to be applicable in determining the plutonium content and burnup of fresh and spent LMFBR assemblies.

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SANDIA PLUTONIUM SHIPPING CONTAINER LICENSED FOR INTERNATIONAL USE

ALBUQUERQUE, N.M.—A plutonium shipping container which can survive a severe aircraft crash and resulting fire has been developed by Sandia National Laboratories and licensed for international use.

The cylindrical container—Plutonium Air Transportable Model 2, or PAT-2—weighs 70 pounds, is 14 inches high and 15 inches in diameter. Licenses permit transport of up to 15 grams of fissile plutonium or plutonium/uranium mixtures in solid form such as oxide powders, sintered oxide pellets, or metal.

PAT-2, developed with sponsorship from the Department of Energy's Office of Safeguards and Security, consists of a double-thick shell of stainless steel with rounded end caps, riveted on the bottom and bolted on the top.

The shell is filled with an outer layer of grain-oriented redwood and an inner layer of maplewood. Sandwiched between the wood layers is a quarter-inch-thick titanium container which spreads impact loads throughout the wood and helps dissipate heat generated by the payload.

Within the innermost wood section is a high-strength, iron-based super alloy sphere about the size of a baseball, closed by 20 bolts and hermetically sealed with a copper gasket. Nested within the sphere is an egg-shaped stainless steel capsule which holds small brass or aluminum canisters that contain the nuclear materials.

PAT-2 is an outgrowth of Sandia's PAT-1, a 500-pound package of similar design, which was licensed in 1978 for domestic air transport of about 3½ kilograms (7½ pounds) of special nuclear material between fuel reprocessing plants, research and development sites, and fabrication plants.

"The development of PAT-2, however, presented an increased design challenge because this smaller package had to survive the same damaging environments during proof testing as its much larger predecessor," says J.A. Andersen, principal designer of PAT-1 and PAT-2.

"Titanium had to be substituted for aluminum as the loadspreader, for instance, and the new package required a super alloy containment sphere instead of one made of steel as in PAT-1."

Nuclear Regulatory Commission and Department of Transportation licenses were issued to PAT-2 after a group of packages survived sequential proof tests. They included:

1) Impact: Impact against an armor-plated unyielding concrete target at speeds of more than 288 mph.
2) Crush: A 70,000-pound load applied through a two-inch-wide steel beam pushed onto the most vulnerable part of the package.
3) Puncture: A 500-pound steel spike dropped onto the package from a height of 10 feet.
4) Slash: A 100-pound, steel angle beam dropped end-on twice onto the PAT-2 from a height of at least 150 feet.
5) Fire: The package placed in a jet fuel fire where temperatures reached at least 1850°F for one hour.
6) Immersion: The charred package submerged in three feet of water for at least eight hours.

"Test results show that if a PAT-2 is involved in a worst-case air crash and subsequent fire, it will release no nuclear materials," Andersen says.

A key to the package's performance is use of wood as a major component. When wood burns, char—a carbon having insulation properties similar to the heat shield of a space vehicle—protects the PAT-2 inner vessels from the fire's heat.

The woods also have extremely good energy absorption characteristics. Redwood has the highest specific energy absorption rate (energy absorption ability based on weight or volume) of any shock-mitigating material; maplewood has an extremely good absolute energy absorption capability.

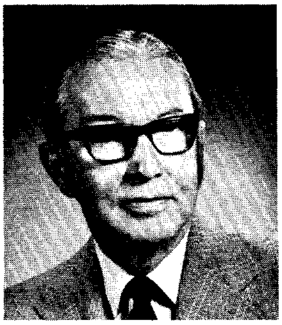
"Nature has built these woods as extremely fine, well-constructed microscopic honeycombs," Andersen says. "Man has not yet been able to duplicate their energy-absorption characteristics, even with the most advanced space-age products."

The NRC license, or Certificate of Compliance, permits use of the container in the U.S. to ship small amounts of radioactive materials used in nuclear safeguards technology research and development projects.

The DOT Certificate of Competent Authority permits use of the container by the International Atomic Energy Agency (IAEA) for shipment of radioactive samples from nuclear processing plants in Nuclear Non-Proliferation Treaty countries to the agency's assay laboratories near Vienna, Austria.

Assaying is designed to confirm that the nuclear materials are being used for electrical power generation and not for weapons fabrication.

HIGINBOTHAM ANNOUNCES DISTINGUISHED SERVICE AWARD NOMINATIONS



Dr. William A. Higinbotham

Nominations are requested for the distinguished service award to be presented at the annual meeting in July. The award, as you know, is for outstanding contributions in the field of safeguards and nuclear materials management.

The Institute depends on you, the members, to send in the nominations, which should include a biographical sketch and a summary of the distinguished service. It would be helpful to the Awards Committee if letters of support could be obtained from other members who are familiar with the work of the nominee.

Nominees need not be Institute members.

Nominations should be sent to:

Mr. W.A. Higinbotham, Chairman
INMM Awards Committee
Brookhaven National Laboratory
Building 197C
Upton, New York 11973

For consideration, nominations and supporting letters must be received by March 31. DO IT NOW!

INSTITUTE OF NUCLEAR MATERIALS MANAGEMENT

INVITATION TO EXHIBIT

23rd INMM Annual Meeting
Washington, D.C. ▪ July 18-21, 1982

The 1982 annual meeting of the Institute of Nuclear Materials Management (INMM) is being held at the Hyatt Regency Hotel, Washington, D.C., July 18-21, 1982. As part of this meeting, the Institute welcomes exhibits which are of interest to INMM members.

Traditionally, the exhibits are simple, informative, and often of the table top variety. The exhibit space will be located in a room immediately adjacent to the meeting room. Coffee breaks and a poster session are planned to give maximum exposure to the exhibits. Booth display hours are limited to normal session hours.

You are invited to participate as an exhibitor in the 1982 meeting. The fee for participation is $350. This fee entitles your organization to space equivalent to one table and one registration for the meeting. A covered table (6 by 3 foot) will be provided. 110V electrical service is available.

Space will be allocated on a first come basis, based on the date of receipt of your check, payable to INMM. Please call me (714/454-3811) if you have any questions. We look forward to your participation in this important meeting.

Sincerely, **TOM McDANIEL,** Exhibits Chairman

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